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FIG. 1. DREDGE LIFTING THE BRIDGE, AFTER DEPOSITING ITS GRAB BUCKET ON THE BANK (11.10 A. M.).

A Novel Drawbridge.

By C. M. KURTZ.*

The embankment of the Sacramento Southern R. R., which is under construction from Sacramento, southerly to Antioch, averages about 20 ft. in height above the general level of the country traversed by it. The embankment is made by dredges casting up the material from borrow-pits on one side or the other of the line.

Wherever the railroad crosses a highway, the latter is carried across the borrow-pit channel by means of a 66-ft. span consisting of two pony Howe trusses. The weight of the span is 15 tons.

The only traffic on the borrow-pits that requires opening of these bridges is the occasional passing of a dredge that might be engaged in the work of repairing the embankment. The bridges are therefore designed to be opened by the passing dredges themselves as they come to them. How this is done may be seen from the accompanying illustrations, from photographs taken on June 7, 1911.

*Construction Department, Southern Pacific Co., 224 Iowa St., San Francisco, Cal.

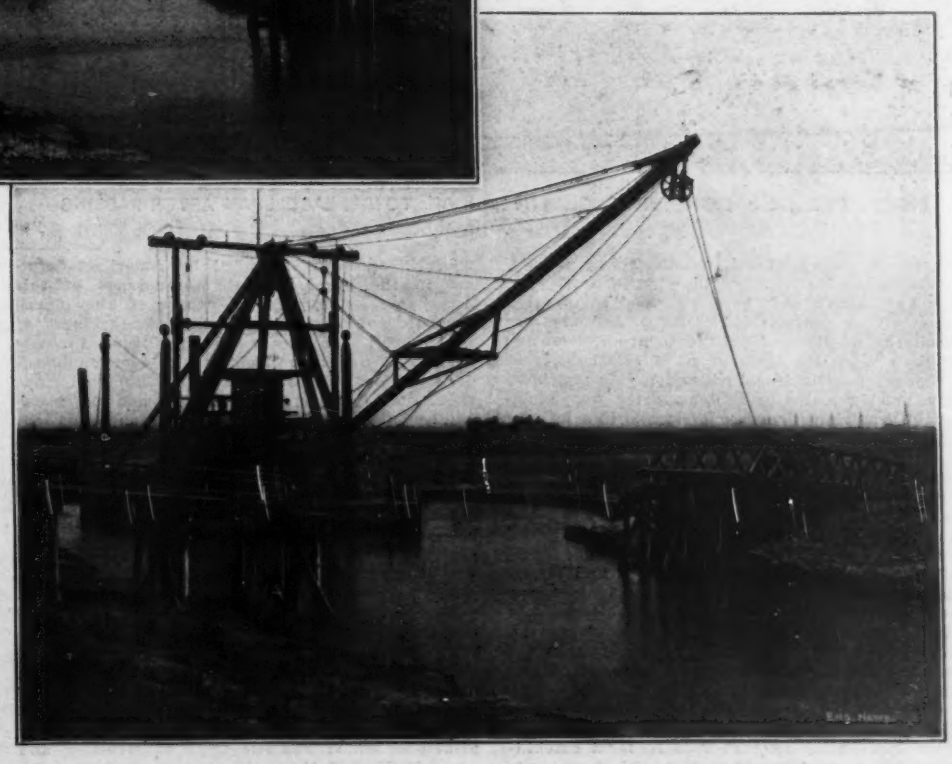


FIG. 2. SETTING BRIDGE ON APPROACH TRESTLE (11.15 A. M.).

The anchor bolts at each end of the bridge are first removed and four single cable slings, made especially for their function and carried by the dredge, are placed in position, taking hold of the bridge near each end of the two middle floor-beams. The dredge bucket is deposited on the shore near by, unfastened from the boom lines and the latter are then engaged to the slings on the bridge. After the span is lifted into the clear, as shown in Fig. 1, it is deposited on the lower approach so as to be entirely clear of the opening, as shown in Fig. 2. The boom lines are then released from the cable slings and again attached to the bucket. Then by manipulating the boom, dipper and spuds the dredge turns itself about and backs through the opening, as shown in Fig. 3.

When it has passed through the opening, the dredge is in position to reverse the operation just described and replace the bridge on its abutments.

The time ordinarily required for a dredge to open and close one of these bridges, as described, is about 2½ hrs., of which time the greater part is consumed by the dredge in making its two turns of 180° each before passing through the opening.

The Paucity of Instruction in Agricultural Engineering in the Land-Grant Colleges.*

Half a century ago engineering attracted little attention. Then only a small number of men followed this vocation, and there were few institutions which gave instruction in the subject. It was not until after the Civil War that men began to recognize the value of technical training and to question the wisdom of compelling all college students to spend so large a part of their time in a study of dead languages and a dead past. Then followed the passage of the Morrill Act, providing for colleges of agriculture and mechanic arts throughout the Union.

The main activities of the land-grant colleges are concentrated upon the training of civil, mechanical, electrical, and mining engineers, in competition with a large number of state universities and technical schools. In their efforts to train civil engineers for railway corporations, mechanical engineers for manufacturers, and hydro-electrical engineers for water companies, these institutions are neglecting to train men for the engineering work of the farm and the country. The movement in that direction dates back but a few years, and as yet only one of the 67 institutions, the Iowa State College, offers a degree in agricultural engineering. Departments of agricultural engineering and of farm mechanics have now been provided in about a dozen of the agricultural colleges, and the men in charge of these departments are illustrating by their work the importance of this subject as a branch of agricultural education. As yet, however, much remains to be done in the way of adequate provision for this subject and in a broader realization of its importance.

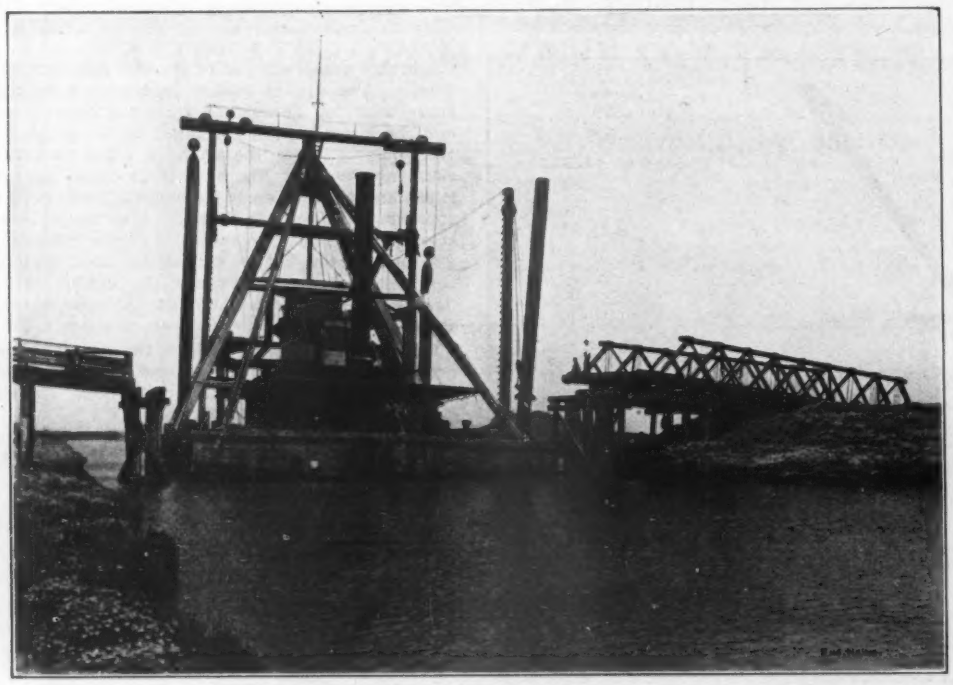


FIG. 3. DREDGE BACKING THROUGH THE BRIDGE, TO REPLACE SPAN AFTER PASSING (12.05 P. M.).

Agricultural engineering as a teaching subject may be divided into six branches, three of which relate to the farm and three to agricultural communities. These are: (1) farm machinery and farm motors, (2) farm structures, including rural architecture, (3) rural water-supplies and sanitation, (4) public roads, (5) drainage, and (6) irrigation. One or more of these divisions is now taught in most of the land-grant colleges, but with a few exceptions they are mainly side issues to what is considered the more important work of training men to become professional engineers. The institutions of this class located in the West give instruction in irrigation as a part of the civil engineering course; those of the Mississippi Valley offer courses in farm machinery and farm motors, while the subject of roads and pavements is included in a large number of engineering courses, but chiefly from the standpoint of the municipal engineer. Rural water-supplies, farm sanitation, and farm structures are for the most part overlooked.

An engineering course combining the course of farm machinery and farm motors as now given in the University of Nebraska and the Iowa Agricultural College, of irrigation as now given in the University of California and the Agricultural College of Colorado, of rural architecture and cement work as given in the University of Wisconsin, and of highway engineering as taught in the University of Kentucky, is in large degree lacking. That there is an urgent need for better and more general training for the engineering work of the farm and the country is evidenced by the large interests represented, and the relation of the subject to the health and comfort of country living and the business side of farming.

According to the report of the Secretary of Agriculture the crops of corn, cotton, wheat, and oats for the past season aggregate a value of nearly three and one-half billion dollars. All four are annual crops requiring the preparation of the soil and subsequent operations of seeding, cultivating, harvesting, and marketing. An attempt to estimate the large number of implements, machines, and motors required for a task of this magnitude brings some realization of what is annually expended by American farmers in the purchase and maintenance of this necessary equipment. The census of 1900 placed the value of farm implements and machinery at $761,000,000, and the annual expenditures for new equipment and new machines at over one hundred million. This was ten years ago and since then not only the number of implements and machines but more particularly the number of motors has been greatly increased.

The simple inexpensive implements used by our fathers have been for the most part replaced by more complicated and more expensive machines. Out of the hand flail of the fifties has been evolved the steam thresher of to-day. The modern harvester does the work of a large number of men, women and children equipped only with the sickle; and motors, trolley cars, and railroads have relegated the saddlebags to the museum. These great changes during the lifetime of men still living, and more particularly the substitution during the past decade of motors for horses and mules, have created a widespread demand for young men possessing a knowledge of agricultural machines and the principles which underlie their construction and use. Studies of this subject are now as essential to the ambitious farm boy as anatomy is to the embryo doctor. The simple arts of mending a flail, whetting a scythe, or harnessing a team have grown into a complicated business demanding not only experience and skill but special training as well.

Nearly fifty years ago the Nation provided for instruction of a kind suitable to the boys and girls on the farm, but the millions of poorly designed farm homes which still mar the landscape are mute evidences that the instruction given did not include rural architecture. The improvement in farm buildings so urgently needed does not call for money so much as a knowledge of how to do things. Out of the same materials, and with very little extra labor, may be built a pleasant, convenient, healthy, and durable country residence, or the reverse. The main difference is one of plan and execution.

Some colleges now give instruction in rural architecture, others in farm architecture, and still others in cement and concrete. But these courses too often deal with urban rather than rural conditions. Undergraduates who are taught to design and supervise the erection of the palatial homes of the rich find the city and its suburbs the most convenient place to practice their profession. The contrast between rural and urban residences is still more strongly emphasized in relation to the water-supplies and sanitation of each. Skilled engineers are employed to provide an ample supply of water for cities, and equally skilled biologists determine its purity, while but little attention is given to farm water-supplies and sanitation.

Farmers procure water for their needs from the same sources which supply water to the residents of cities. These are springs, wells, cisterns, reservoirs, lakes, and rivers; but the training and experience necessary to utilize such sources for the benefit of the one class differ in many essentials from those of the other. The civil engineer may succeed in building a distributing reservoir for a city and yet fail in his effort to build a cistern for a farmer. His computations for a high water tower may be correct and those for a windmill wholly wrong in principle. It is true both belong to hydraulic engineering; but so long as engineers are trained to solve the problems of the city and to neglect those of the country, we need not expect a high class of engineering on the farm.

Western farmers deserve great credit for the lands they have reclaimed, but their task is not completed. So great is the waste of water at present that from 50 to 100% more land might be reclaimed if the waste waters were saved and utilized. It is, however, doubtful if the farmers will accomplish this reform by their unaided efforts. They have gone about as far as they can without the assistance and supervision of the trained specialist.

All over the irrigated West, from every district and from nearly every farm, and also from the drought-stricken states of the East and Middle East, comes the call for help. How shall I line my ditch to prevent loss from seepage; how much water is needed for this and that crop, and when should it be applied; how shall I prepare my fields so that the ditch water will moisten the soil uniformly; and what is the most suitable device for measuring water? In other instances information is wanted on the construction of reservoirs and tanks, the installation of pumps, the erection of windmills, and the drainage of seeped lands.

These calls for help come with every mail to both the Department of Agriculture and the agricultural colleges and experiment stations. Even in the West only a few of the agricultural colleges maintain strong departments in irrigation commensurate with the importance of the subject and its efficient investigation.

Taken as a whole, the land-grant colleges may be said to have expended little effort or money in training specialists for engineering work of agricultural communities. This is perhaps not strange, for in the past the demand for engineers has been largely in connection with municipal and development work. But the present interest in agricultural development, in making land more efficient in production, and in the improvement of rural conditions in a variety of directions, has opened the way for the agricultural engineer and calls for the adequate development of the subject at the agricultural colleges. The field is broadening year by year, and in many cases is already being occupied by men who have had no contact with agricultural conditions or problems.

Unless the curricula of the engineering courses of these institutions are modified there is certain to be overcrowding in the older branches of the engineering profession. Meanwhile progress in agriculture and the improvement of rural districts are being immeasurably retarded through the lack of competent agricultural engineers.

*Condensed from an editorial discussion in the U. S. "Experiment Station Record" (February, 1911), U. S. Department of Agriculture.

An Electrically Driven Pumping Plant for City Water-Supply at Oakland, Cal.

By GASKELL S. JACOBS.*

A notable installation of electrically driven turbine pumps has recently been made at the new Diamond pumping plant of the People's Water Co. at 40th and Diamond Sts., Oakland, Cal. In 1907, to meet the demands of water-supply in the rapidly growing districts of North Oakland and Berkeley and to supplement the Berkeley supplies, a steam driven reciprocating pumping plant of about six million gallons daily capacity was installed in this locality. This temporary plant showed considerable deterioration, and as the requirements of the district became more definitely established, it was decided to abandon and dismantle the steam plant and install a permanent booster plant in its place. Since satisfactory arrangements for a dependable supply of electric power could be made at a low price, a consideration of the low first cost of an electric plant, its smaller attendance charges, maintenance and depreciation resulted in the decision to install an electrically operated station. The subsequent performance and reduced operating costs of the plant, which has been running since June 1, 1911, have confirmed the wisdom of this decision.

MOTOR-DRIVEN TURBINE PUMPING STATION FOR BOOSTER SERVICE AT OAKLAND, CAL.

The plant is located on the east side of Diamond St., south of 40th, opposite the old steam station, at an elevation of about 83 ft. The plant is housed in an ample, well-lighted building 30 × 44 ft. in plan. The walls, 18 ft. high, are of reinforced concrete, with a steel roof structure and concrete slab roof and floors. The walls are finished inside and out with cement plaster. At night the station is lighted by six clusters of 60-watt tungsten lamps, three lamps in each cluster. A small room containing lockers, stores and conveniences is partitioned off at a rear corner of the building.

The present installation provides for a pumping capacity of 6,000,000 gals. daily under a variable head of from 220 to 280 ft. There are now three units, but space is left for a fourth similar unit which will make the ultimate capacity 8,000,000 gals. per day as a provision for future increase in consumption. The supply is taken from a 16-in. main on 40th St. into which are connected the ends of the net work of the distributing pipes of the city of Oakland, and is carried into the station through two 10-in. intake pipes with regulating gates operated inside the building. The discharge main, 16 ins. in diameter and over 13,000 ft. long, runs out Broadway, College Ave., and Webster St. to Claremont Reservoir, situated at an elevation of 295 ft. (212 ft. above the pumps), supplying the intermediate sections of Oakland and Berkeley through branch mains and, in addition, a part of the Linda Vista district. At night, the pressure is high, and the water flows directly to the reservoir; during the day, however, the pressure at the pumps is reduced due to the use of water along the line, and the supply is then furnished from both ends of the main. The pumps respond easily to these variations in pressure and delivery and are so designed as to keep approximately constant full load on the motors without a reduction in efficiency.*

The water flows from the mains supplied by the principal pumping station at a lower level into a covered sump 20 ft. in diameter and 7 ft. deep at the rear of the building. An electrically operated high and low water alarm is provided. From the sump the water flows through a tunnel under the building, in which are the pits for the suction pipes which pass through openings in the floor above. A 12-in. tile drain leading to a nearby storm sewer carries the overflow from the tunnel.

An interior view of the station is shown in the accompanying illustration. There are three 8-in., two-stage, horizontal turbine pumps running at a speed of 1,780 r. p. m., direct-connected by flexible leather-link couplings to 440-volt three-phase induction motors rated at 150 HP. each. The pumps are fitted with ring-rolling bearings, water-sealed stuffing boxes, enclosed non-overloading runners, renewable diffusion vanes and adjustable thrust balance. They are primed by direct pressure from the mains, the suctions being provided with foot valves. The discharge pressure varies from 95 to 120 lbs. per sq. in., and the suction lift averages 9 ft. with a delivery of 1,800 to 1,400 gals. per minute, over which range a pump efficiency of better than 70% is maintained. The induction motors have squirrel-cage windings and enclosed frames, with ventilating fan blades attached to rotor. Their normal full-load power factor is 96%, and under the steady full load they show a high efficiency. They are mounted on the extended base plates of the pumps.

The operation of the station is noticeable for its smoothness, uniformity and the absence of all shock and disturbance in the discharge main. Each pump discharge is fitted with check and gate valves and long sweep fittings connect them to the 16-in. discharge header. These gates are not manipulated while the pumps are running, as the pumps automatically respond to all changes of pressure and delivery. The intakes and discharge mains are regulated by a group of valves set in a pit at the front of the building and operated from wheel stands above. In full view of the operator at the wheels are placed the indicating gages mounted on a slate panel.

The power demand of the station is uniform and continuous throughout the day and night, and is supplied from a three-phase, four-wire, 4,000-volt line from the Temescal sub-station of the Oakland Gas, Light & Heat Co. It is connected through an underground conduit and an 11,000-volt oil station switch to a bank of three 125-KW. transformers placed within the building and stepping down to 440 volts for the motors. These transformers are supplied with 220-volt taps for starting the motors, thus obviating the use of starting compensators.

The switchboard, shown in the illustration herewith, consists of five slate panels, one for the station switch and meters and the four remaining for the triple-pole double-throw oil switches. These switches are provided with overload and no-voltage releases and are interlocked, being used to throw over the motors from the starting to running voltage. All the bus bars, wiring, current and potential transformers for meters, high tension feeders and switchboard panels are carried on a pipe frame, which also serves as a railing enclosure for the transformers and switchboard apparatus. All conduits for wires supplying light and power are concealed in the walls and floor of the building, and all small water pipes for station use and pump priming are buried in the concrete floor. The drains from the pumps discharge into a vitrified conduit under the floor connecting with the overflow. The motor leads are three-conductor lead-covered cables running in conduits under the floor from the switches back of the switchboard to the motor terminals, both ends being provided with porcelain outlet bushings.

To measure, indicate and register the delivery from the pumps, a 16 × 8-in. Venturi meter is set in the main discharge line just outside the building. The pressure pipes from the meter run to an automatic indicator and recorder mounted at the end of the main switchboard. Each pump is equipped with pressure and vacuum gages. The station output is measured by recording pressure gages and the recording Venturi meter, while the switchboard instruments account for all the power consumed, so that the performance of the station at all times is definitely known.

The pumps were furnished by the Byron Jackson Iron Works, of San Francisco, Cal., and the switches, switchboard, motors, transformers and other electrical equipment were supplied by the General Electric Co. The complete design and plans for the station, the pumping and electrical equipment, construction of the building and installation of the machinery were in charge of the writer as Assistant Engineer of the People's Water Co.

*Formerly Assistant Engineer, People's Water Co., Oakland, Cal.; now of 2327 Cedar St., Berkeley, Cal.

*See article on "Development of Centrifugal Pumps," Eng. News, Nov. 11, 1909, p. 505.

The Vertical-lift Drawbridge, with the span raised and lowered between towers on either side is being used in a number of cases for both railway and highway structures. A bridge over the Missouri at Kansas City, where only a low headway is required, has a 428-ft. fixed span over the channel, from which the railway deck is suspended. When boats approach, this deck is raised by cables to the level of the bottom chord of the fixed span, giving a clear headway of 65 ft. At Portland, Ore., a 220-ft. through truss span carries the railway on its lower deck (level with the top chord of the approach spans), and from it is suspended a highway deck. For small vessels, the highway deck is raised to the bottom chord of the truss; but for large vessels with tall masts the truss also is raised between the towers. Three railway bridges of this type are to be built over the Calumet River at South Chicago; one is a four-track bridge for the Lake Shore & Michigan Southern Ry. and the others are two double-track bridges (side by side) for the Pennsylvania R. R. These are all skew spans 210 ft. long, with a clear waterway of 140 ft. and a vertical lift of 120 ft. above water level. The substructures will be concrete piers resting on bed rock. The plans for these bridges are being prepared by Waddell & Harrington, consulting engineers, of Kansas City, Mo., who also designed the other bridges above mentioned. The Halsted St. bridge at Chicago was one of the first large bridges of this type, and was designed by Mr. J. A. L. Waddell, M. Am. Soc. C. E. This was built in 1894.

A Remarkable Concrete Arch Dam.

A 60-ft. plain concrete arch dam, only 5.2 ft. thick at the base, has been built on Crowley Creek, Malheur County, Oregon. The dam is owned by the Malheur Live Stock Land Co. and was designed by Mr. A. J. Wiley, M. Am. Soc. C. E., of Boise, Idaho, to whom we are indebted for the plans and data here given.

At the dam site the creek valley is contracted by lava walls to a width of about 35 ft. at the bottom, and 125 ft. at a height of 60 ft. The entire cross-section of the valley, shown in the accompanying cut, is in hard lava rock. The dam site is 85 miles from the nearest railway.

The dam is built of gravel concrete without reinforcement of any kind. The cement used was an imported English brand and was mixed in the proportion of one barrel of cement to a cubic yard of concrete. The dam contains 800 cu. yds. of concrete and cost about $12,000.

In designing the dam it was assumed that the entire water pressure would be transmitted horizontally through the arch to the abutments, the weight of the dam being neglected. The maximum allowable compressive stress upon the concrete was taken at 25 tons per square foot. The dam was designed as a vertical cylinder subjected to external water pressure, and the thickness of the arch rings at various depths computed by Navier's formula. The radius of its upstream face is 70 ft.

The maximum height of the dam was made 60 ft. above bed rock. The thickness at the base is 5.2 ft., and at the top 3 ft. The thickness continues as 3 ft. to a point 30 ft. below the top where it gradually increases to the full thickness at the base. The upstream face is vertical, all the batter being placed on the downstream side. The dam is 150 ft. long on the crest and 170 ft. long over all. At the base the length is about 40 ft.

To protect the toe of the dam from the impact of the water passing over its crest, a second lower dam concentric with the first was built. This lower dam is 10 ft. high and is located 35 ft. below the main dam, with its upstream face on a radius of 35 ft. Its thickness is 3 ft. This dam forms a water cushion between the two dams to protect the base of the main dam from erosion by the falling water.

The outlet of the reservoir is through two 12-in. cast-iron pipes, 15 ft. above the base of the dam. These pipes are cast into the concrete and are fitted on their downstream ends with high-pressure water-works valves. The valves are protected from the falling water and made accessible by a concrete dome. The upstream ends of the pipes are protected by a grillage of timber.

The dam has now been in successful operation for several years, and has been subjected to overflows to the depth of 2 ft. for long periods of time. Heavy ice-flows have also occurred. The water stored is used for irrigation purposes. For some time after the completion of the dam the reservoir leaked badly through crevices in the rock sides, but these have gradually closed and the reservoir is now reasonably tight.

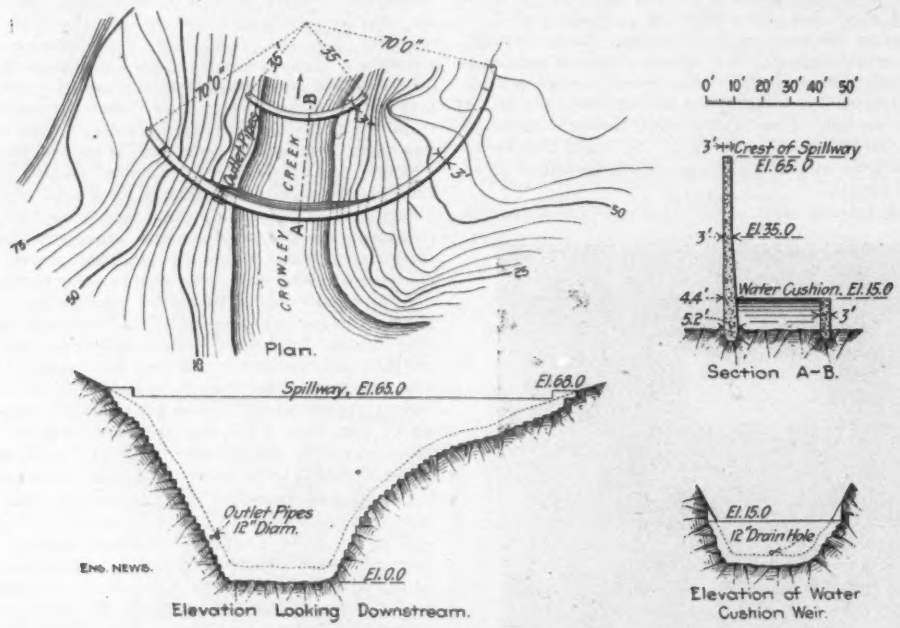


FIG. 1. PLAN AND ELEVATION AND CROSS-SECTION OF THE CROWLEY CREEK CONCRETE ARCH DAM, MALHEUR COUNTY, OREGON.

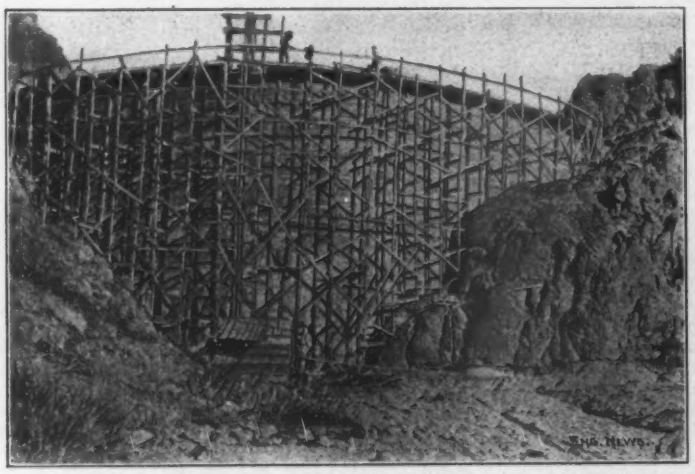


FIG. 2. VIEW OF CROWLEY CREEK CONCRETE ARCH DAM, WITH CONSTRUCTION STAGING IN PLACE.

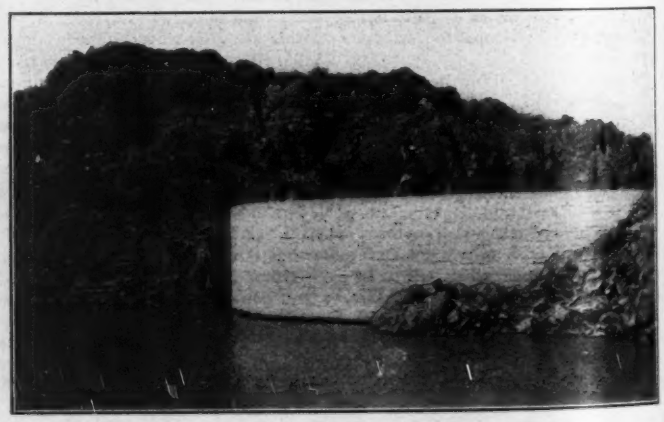


FIG. 3. VIEW OF DAM AFTER COMPLETION.

Ultra-Violet Ray Purification of Water has been reported on by Messrs. Grimm and Weldert, of the Royal Institute of Tests for the Distribution of Potable Water and Disposal of Sewage, located in Berlin, in the July, 1911, issue of "La Technique Sanitaire et Municipal." These investigators made an extensive study of a small ultra-violet ray unit, under service conditions, and give tabular statements of the degree of sterilization which can be produced in waters of various degrees of pollution. The report is chiefly remarkable for the very low effectiveness in output of the method and the high cost shown by the experiments. In previous reports (Eng. News, Sept. 15, 1910, p. 275; Dec. 8, 1910, p. 633), on this method of sterilization, it has been stated that an ordinary 220-volt, 3-amp. machine could sterilize about 160,000 gals. of ordinarily polluted water in 24 hrs. at a cost of about $10 per million gals. Messrs. Grimm and Weldert found that a machine working with 120 volts, 4 amp., could produce only 3,000 gals. per 24 hrs. at a cost of $10 per 34,600 gals. This difference is so great that it would seem that the units operated by Messrs. Grimm and Weldert were not working up to their full efficiency, or else the apparatus was not of the best type. The experimenters report, however, that the degree of sterilization possible with the apparatus is nearly perfect and that except for the high cost the method is most effective.

Steel Motor Cars are being equipped by the Pennsylvania R. R. for the rapid-transit line which that company will operate between Newark, N. J., and the Hudson Terminal Building, New York City, entering that city over the line of the Hudson & Manhattan R. R. (McAdoo Tunnels). These cars are smaller than the cars of the Pennsylvania R. R. operated over the main line to the 34th St. terminal, being 48 ft. long over ends and 11 ft. 8½ ins. high from top of rail to top of roof. The widths are (1) over eaves 8 ft. $7^{13}/_{16}$ ins., (2) over side door threshold plates 8 ft. 10½ ins. Center and end doors are used with pneumatic operating gear and electric door signals. The body center girder is a box type 6¾ ins. deep over trucks and 9¾ ins. at the center, having an area of 25 sq. ins. cross-section compared with 33⅓ sq. ins. for light suburban passenger cars on steam service. The top cover plate is 2 ft. 6 ins. wide and the bottom 1 ft. 10 ins. The superstructure is carried on two cross bearers and two end sills. The main strength of the side framing is below the windows.

Each truck has one motor and one trailer axle, the center line of bolster being 2 ins. off truck center toward the trailer. The motors are a 225-HP, 600-volt commutating-pole direct-current type. The gear is carried on the extended hub of one wheel. The motor frame carries two lugs in front resting on the truck transom; the axle bearing caps are bolted to vertically planed tongued surfaces on the truck frame. The air-brake equipment is like that used by this railway, but arranged to bear harder on the motor than on the trailing axle. Multiple-unit control gives four positions ahead and two reversed, the contactors being under the floor. For emergency lighting a small storage battery is installed. The car weighs 72,500 lbs.

The Corrosion of the 350-Mile 30-in. Coolgardie Steel Pipe Line, Western Australia.

The 30-in. Coolgardie steel water-supply main, which with the aid of eight pumping stations conveys water 351¼ miles, with a total maximum lift of 1,290 ft., to supply the Coolgardie Goldfields, in Western Australia, gave evidence of corrosion only two years after the conduit was in full operation and seven years after construction was started. Studies of the corrosion were begun immediately (1905) and were continued by engineers and chemists, both local and British, until 1910, when the final recommendations for dealing with the corrosion were put under execution. Before this, however, the worst portions of the corroded pipe were overhauled. The various reports on this interesting problem were published in pamphlet form some months since. We are indebted to Mr. W. C. Reynoldson, Chief Engineer Goldfields Water Supply, Perth, Western Australia, for a copy of the pamphlet. The following information on the corrosion of the conduit and related subjects has been collated from the various reports mentioned and has been rearranged to bring the related parts more closely together than the chronological order of the reports permitted in the original.

General Description of Conduit.

The water supplied by the Coolgardie conduit is from the Helena River, in the Darling Ranges, and is impounded in a reservoir of about 5,500,000,000 U. S. gals. located some 18 miles from Perth, which is not far from the Indian Ocean. The river has a drainage area of 569 sq. mi. above the reservoir.

The first pumping station draws from the impounding reservoir and the others draw water from tanks into which the water is delivered through bellmouth pipes, with the discharge at the surface level. This mode of delivery, combined with other features of the pipe line and accessories, affords ready means for keeping the water in the pipe charged with air, a fact taken into consideration throughout the various reports.

The first receiving and suction tank has a capacity of about 560,000 U. S. gals.; the second, 12,000,000; the next five, 1,200,000 gals. each. The eighth pumping station delivers water into a 14,400,000-gal. (U. S.) service reservoir, 1,290 ft. above the lowest outlet pipe of the impounding reservoir and 307½ miles therefrom or 306 miles from the first pumping station, which is 1½ miles from the impounding reservoir. Water flows by gravity through the remaining 44 miles of the pipe line, on which there is a 1,200,000 and also a 2,400,000-gal. (U. S.) service reservoir. It will be noted that the receiving and service reservoirs afford very little reserve capacity, thus making the integrity of the pipe line of unusual importance. It should also be noted, as Mr. Reynoldson points out, that so long a pipe line might be kept out of service a large percentage of the time even though the breaks per unit of time and length of conduit were not excessive, since a break at almost any point would throw the whole line out of service until repairs were made. In fact, Mr. Reynoldson states that "one break a week in rotation on each section between No. 3 Station and Kalgoorlie would practically mean that no water could be passed through."

Perhaps it should be explained that while the report states that

> water is distributed to the various townships en route, and to mining centers from service reservoirs, and a considerable area of agricultural country is also supplied by branch lines from the main conduit

yet it appears that the bulk of the whole supply is delivered near the extreme end of the line. Thus, for the year ending October, 1908, the average daily pumpage was about 3,000,000 U. S. gals. at Station No. 1, 2,400,000 at Station No. 6 (about 220 miles from the impounding reservoir), and 2,265,000 U. S. gals at Station No. 8.

The entire cost of the Coolgardie water-supply up to June 30, 1909, was £3,260,000 ($15,844,000), of which £2,140,000 ($10,400,000) was for the steel conduit.

The steel conduit is composed of ¼-in. plates where under a head of not more than 390 ft. and of 5/16-in. plates where over that head. The longitudinal joints are of the locking-bar type and the circumferential joints were made with welded steel collars, caulked with lead from face to face of collar. The plates and bars were imported into Western Australia and there made into pipe. Open-hearth basic steel was used, with a tensile strength of 25 to 29 (long) tons (56,000 to 64,960 lbs.) per sq. in. for the plates and 22 to 26 tons (49,280 to 58,240 lbs.) for the bars. Continuing in Mr. Reynoldson's own words, as given in his "General Description of the Work":

> The manufacture of the pipes, including the cutting, dovetailing and rolling of the plates and the closing of the locking bars on to the plates, was carried out without heating either the plates or the locking bars.
>
> Every care was taken to thoroughly cleanse the plates of all mill scale, the bulk of which was detached by the process of bending and rolling, and the remainder by steel wire brushes.
>
> The completed pipes were tested by water pressure of 400 lbs. per sq. in. and, on passing this test satisfactorily, were heated to 300° F. and immersed in a mixture of coal tar and Trinidad asphaltum maintained at the boiling temperature of the mixture. [A different material was used for coating 85 miles of the line, as stated further on.]
>
> On removal from the dip the pipes were drained and then revolved in a horizontal position by a machine to ensure a uniform thickness of coating. To accelerate the cooling a current of air was blown through the pipe while rotating.
>
> For the purpose of making the coating more resistant to flowing under the sun's heat, a sprinkling of fine sand was thrown over the outside of the coating when it had become nearly set and lightly pressed into its surface by means of rollers.
>
> The pipes were conveyed from the factory by railway and distributed along the route, which, for the most part, lies adjacent to the railway line to the Eastern Goldfields.
>
> Care was taken in loading, transporting, and distributing to protect the coating from damage as far as possible and, immediately before being placed in the trench, any defective parts were made good with a mixture of tar and asphalt applied hot.*
>
> For the greater part of its length the main is buried and has a covering of earth, about 2 ft. 3 ins. in thickness, above the top of the pipe. Where the pipe line crosses the salt lakes it is carried on wooden trestles and is surrounded by an insulation of sawdust to a thickness of about 9 ins. held in place by a galvanized casing.
>
> Water was first admitted to the main in April, 1902, and the charging went ahead as each section of the main was completed, the water finally reaching Kalgoorlie in January, 1903.
>
> From tests made on the carrying capacity of the main in September, 1903, the friction head per mile when delivering 5,600,000 gals. [6,720,000 U. S. gals.] per 24 hrs. was found to be 2.85 ft.

The coal tar was added to the crude Trinidad asphalt to bring it to the desired consistency. The temperatures ranged from below freezing to 170° F. To prevent brittleness at the lower temperatures the coating was made so soft that without the sand already mentioned it would run at the higher temperatures. Quoting again from Mr. Reynoldson:

> It is admitted that sanding is not desirable, and my own opinion is that soft coatings, owing to their liability to flow, are not so good or so reliable as the hard coatings. In fact, I consider hard coatings better than soft, as they are denser and more durable and have a better contact with the metal. These advantages more than offset the small amount of flaking experienced whilst handling the hard coatings. Moreover, with hard coatings any thickness can be obtained by repeated dippings, whereas thick soft coatings are always likely to flow. By reducing the asphaltum and increasing the tar, any required degree of hardness can be obtained by boiling.

Not all the pipe was treated with asphalt and tar. About 85 miles were coated with 2½ parts of "Trinidad bitumen" (evidently crude Trinidad asphalt) and "one part of liquid S. California maltha, which had been applied to a 6-ft. steel main made by G. & C. Hoskins for the Sydney Water Supply"—which firm also had the contract for a part of the Coolgardie pipe line. When 85 miles of the pipe on the Hoskins contract had been laid "it was found that the coating of the earlier-made pipes was showing conditions of perishing," and the use of the bitumen and maltha was discontinued. The other contract was let to Mr. Mephon Ferguson, who used the asphalt and the coating already described. Sand, it appears, was rolled into all the coating on both contracts.

*At another point in the report it is stated that: "The special truck cradles on which the pipe rested were cushioned with bagging, and the pipes were kept from coming in contact with each other during transport by rope bolsters, and the skids down which the pipes were lowered from the trucks had their ends protected with rawhide."

Nature and Extent of Corrosion.

The progress of the corrosion of the pipe is not set forth in much detail in the various reports before us.

EXTERNAL CORROSION.—Of this Mr. Reynoldson says:

> External pitting of the pipe was first noticed early in March, 1905. In June, 1905, or 2½ years after laying [or being put in service] a rust hole occurred in a depression in a clay flat which, on examination, was found to have been caused by external pitting. Immediately this was discovered steps were at once taken to arrest further damage. A preliminary examination of the main was made at all low points throughout its length, and wherever pitting was found, the pipe was uncovered, the old coating scraped off, and then recoated.

It will be remembered that water was first admitted to the conduit in April, 1902, and reached the further end in January, 1903. Most of the pipe was distributed and left above ground from 12 to 24 months before it was laid, that at the end furthest from the impounding reservoir having been alongside the trench the greatest length of time. This, Mr. Reynoldson thinks, had little or nothing to do with the corrosion.

Between June, 1905, and November, 1908, 151 leaks occurred, or one to each seven miles of pipe per year. Comparing this with the 143 leaks on the steel main of Rochester, N. Y., to the end of 1907 (nearly one per mile per year), Mr. Reynoldson says

> it would therefore appear that, although corrosion started at an earlier date in the Coolgardie than in the Rochester main, its extent has not been as general.

To April 6, 1909, there had not been "one perforation of the pipe resulting from interior corrosion" (but there had been serious interior tuberculation, as will appear later).

As already intimated, the external corrosion is worst in low wet clayey places. The bad effect of moisture is strikingly illustrated at a point where a boiler blow-off drain kept the earth moist along the pipe. Here not less than 80% of the pitting "was found to be on the side of the pipe nearest the drain, where the surrounding soil (red loamy clay) contains more moisture than the soil on the side furthest from the drain."

INTERNAL CORROSION AND TUBERCULATION.—The possibility of internal corrosion or tuberculation was first thought of early in 1906, owing to the increased pumping head at Station No. 7. This increase was at first laid "to accumulation of deposits" at low points in the conduit, due, in turn to the (temporary?) omission of scour valves in this section. Up to 1906 the pumping head had increased but slightly on the other sections of the force main, while the three or four pieces of defective pipe thus far removed (all in other sections)

> were found to be in very good condition, being almost wholly free from tuberculation, but it was noticed in some instances that small tubercles had formed at points along the line traversed by the wheels of the expander used in the operation of making lead joints.

A friction test in this section of the main was made in October to December, 1906, and "showed that a considerable increase in friction through this section had taken place since the main was laid. Subsequently the whole main was tested in like manner, and the test was repeated in the middle and latter part of 1908. The reduction in carrying capacity in the section of conduit beginning at No. 7 station was 40% (after about five years). At this time, however, the gravity section next below No. 8 station showed a reduction of 44% and the one next below that of

53%. The reductions in other sections ranged from 12 to 31%. All of the poorest results were in sections having high percentages of their lengths treated with the maltha coating already mentioned.

Further information regarding internal corrosion or tuberculation, from Mr. Reynoldson's report of Nov. 24, 1908, under the heading, "Probable Life of Main," is as follows:

An examination of a number of pipes which have been removed from various sections of the main shows conclusively that the increase in frictional resistance is a direct measure of the extent of corrosion.

On the section where friction is least tuberculation is least, and where friction is greatest tuberculation is also greatest.

The tubercles are formed from the corroded metal, and consequently the larger the tubercle the greater the corrosion.

Even under the smallest tubercles—those not larger than the size of peas—a small pitting of the metal is found.

As the tubercle increases in size the pitting increases in depth and area, but there appears to be a critical depth, viz., about ⅛-in., beyond which no further penetration takes place, but the corroded area keeps on extending until it merges into and becomes confluent with the corrosion under the surrounding tubercles.

This depth is an extremely important factor in the life of the main, as it is anticipated that ultimate failure will result from isolated internal pittings and not from the weakening of the plate from general corrosion.

Pittings of the plate to the depth of ⅛-in. are quite common, but never in all the pipes personally examined or reported on by the district engineers has a greater depth than this been observed.

Although this critical depth has not been specifically commented upon in the literature on the subject, pittings to the depth of an eighth of an inch are frequently referred to, but it is rarely stated that pittings of a greater depth have been noted.

The tubercles resemble mussels or limpets, and the majority grow with their length at right angles to the direction of the flow of the water and have steep upstream and sloping downstream sides. The diminution in the carrying capacity is not so much due to the reduction in the sectional area of the pipe as to the very great roughness caused by the arrangement of the tubercles.

On Oct. 20, 1908, a pipe was removed on the section between Bulla Bulling and Coolgardie, where the reduction of the flow, due to tuberculation, is greatest. Nearly the whole of the bottom plate of this pipe was covered with tubercles and about 80% of that of the top plate. The largest of these tubercles did not project more than 1¼ ins. from the surface of the plate of the pipe, yet owing to the resistance to flow set up by the roughness, the carrying capacity of the pipe through this section was no greater than that of a 22-in. smooth, clean pipe.*

There was ample evidence that the original coating (maltha mixture) of this pipe was very bad, and I consider its condition as regards tuberculation and corrosion to be representative of the worst pipes throughout the full length of the main. A film covering about 30% of the whole surface of the bottom plate and 15% of that of the top plate of the pipe was eaten away by corrosion to a depth of about 1/64-in. with innumerable isolated pittings reaching to a maximum depth of ⅛-in.

Externally, although the coating was perished, the metal was free from corrosion and in excellent condition. The locking-bar joints were also in good order, and it is satisfactory to note that the joints of all other pipes which have been examined from time to time have also been found to be in fair order.

As this was a new form of joint, a certain amount of anxiety was felt as to how it would stand the test of time. Up to date only two locking-bar joint failures have occurred throughout the whole 352 miles of main comprising upwards of 120,000 joints. The evidence is that occasional failure of the locking-bar joint will occur, but that ultimate failure of the main will not result from inability of the locking bars to hold the plates together.

The evidence of the Coolgardie main is fairly conclusive that ultimate failure, if corrosion be not checked, will result from internal not external corrosion, although the latter will be an assisting factor. It is to be expected that the number of external rust-hole penetrations will increase as time goes on, but the section of pipes attacked are confined to short lengths, and the pittings are localized and are under control and can, in the majority of cases, be repaired without stopping the pumps.

Internal corrosion though slower than external is more uniform and insidious, and extends throughout the whole length of the main from the reservoir to Kalgoorlie, and it is to be expected that after their first appearance rust holes will increase rapidly.

The quantity of water which will be lost by leakage during the time which must necessarily elapse between the appearance of each individual leak and its repair, although small will, in consequence of the great number of leaks spread over such a long length of main, amount in the aggregate to a serious percentage of the total amount of water which can be passed through from the Helena Reservoir.

When leakage is considered, the length of the main alone is the governing factor in the useful life of the main—5% loss of leakage on a twenty-mile section might not in itself be serious, but when extended to a main 350 miles long, it amounts to nearly 90% of the total quantity which can be pumped from the source of supply.

When it is remembered that steel has only been used for water conduits for about 20 years, and the many uncertain factors entering into the subject of corrosion of steel water mains, either dealt with or referred to in this report, it will be evident that the life of such mains can not be predicted with any great degree of accuracy.

A close observation of the progress of corrosion of the Coolgardie main, together with a consideration of all the evidence bearing on the corrosion of steel water mains generelly, leads me to the conclusion that, with efficient maintenance, it should be possible to keep the conduit serviceable for a further term of ten years without opening up, taking out, cleaning, recoating and relaying.

Other statements regarding the tuberculation of the pipe are found in a report by Mr. E. A. Mann, Government Analyst of Western Australia, dated Nov. 25, 1908. Mr. Mann says:

The tubercles are all alike in structure and character. It is found when one is removed that it covers at its center a pit in the metal varying in depth and extent. The extreme depth to which the pits have extended appears to be about ⅛-in., and they seem to manifest a tendency to spread in a lateral direction. **The entire area of corrosion is covered by a tubercle which has evidently formed from the metal dissolved from the cavity.** A small drop of moisture is generally found in the depression under the center of the tubercle, and the latter immediately over this point exhibits a small core which is black in color, extending beyond this again outwards are layers of soft plastic material varying from a light yellow to reddish color forming excrescences sometimes of considerable size.

The interior corrosion, Mr. Reynoldson states, "generally" begins "where the coating is thinnest and where it first perishes." Again he says:

* * * whole patches of the coating, both of the maltha mixture and also of the tar and bitumen [Trinidad asphalt] composition, but more particularly of the former, have undoubtedly completely perished. Even where no corrosion has as yet occurred, the coating is undergoing decay. This decay starts from the water surface of the coating.

* * * * * * * * *

Generally the cast-iron portions [valves and specials and Venturi meters?] are more tuberculated and in a worse condition than the steel main.

Cause of the Corrosion.

Running through the many reports composing the pamphlet are various attempts to explain the cause of corrosion. These attempts range from casual remarks of one or two sentences to many paragraphs and from familiar causes to the latest electrolytic theories. They deal with the character of the metal, its coating, the soil in which the conduit is laid and the water conveyed by the pipe. The coating has already been described, and it is evident that whatever the causes back of the failure, the coating did fail to do its work. There is little evidence as to the character of the metal, except that already given. Mr. Mann, in the report already quoted from, states that the pipe specifications did not extend beyond the tensile strength requirements. In another place Mr. Mann gives the composition of the steel as: carbon, 0.173%; phosphorus, 0.035; sulphur, 0.060; manganese, 0.432; silicon, 0.01. He adds that there is no direct evidence that the impurities in the steel "have been an important factor in the case."

SOIL.—As early as April 6, 1905, Mr. Edward Simpson, Government Mineralogist and Assayer for Western Australia, reported on three samples of soil submitted to him by Mr. Reynoldson. The origin of these soils in relation to the corrosion of the pipe is not stated.

As to the conditions under which "steel or iron pipes in contact with soil may be expected to corrode" Mr. Simpson stated:

(1) From the action of rain water containing in solution oxygen and carbonic acid and kept mechanically in contact with the pipes by soil. Corrosion from this cause will go on no matter what the composition of the soil, though its effect appears to be enhanced by the presence of soluble chlorides.

(2) From the presence in the soil of free acid or of pyrites which, in oxidizing under the influence of moist air, liberate sulphuric acid.

(3) From the presence in the soil of soluble salts having an oxidizing action on iron, principally nitrates and magnesian chlorides. These salts cannot affect the pipes when the soil is perfectly dry, but only when brought into solution by being moistened.

The samples analyzed contained no pyrites nor free acid. Their composition, as regards soluble salts, was as follows:

Insoluble in water....	98.7527	98.0011	98.7740
Calcium carbonate.....	.0241	.0223	.0260
Calcium sulphate.....	.1214	.6107	.2049
Magnesium sulphate .	.1616	.2118	.1847
Potassium sulphate ..	.0052	.0028	.0063
Sodium sulphate	.6928	.7639	.1285
Sodium nitrate	.0096	.0078	.1614
Sodium chloride	.2326	.3796	.5142
	100.0000	100.0000	100.0000

The only one of these salts mentioned in the report as liable to cause corrosion was sodium nitrate, "which, especially in conjunction with a soluble chloride, such as sodium chloride, rapidly attacks steel or iron." This (sodium nitrate) was found in all three samples, but only in the third was the amount "worth considering." Mr. Mann stated that corrosion where this sample was taken "may be expected to be far more rapid than at the other places sampled," but whether this was found to be true none of the reports state.

Finally, Mr. Simpson suggested that where moisture prevails much may be done to protect the pipe by drainage and by protecting it from rain and preventing leakage, "especially in those sections where the nature of the soil is such as specially to assist corrosion."

In the following year (1906) Mr. Simpson made two reports on prevention of corrosion of the pipe line, in which he included a large additional number (30 and 29, respectively) of soil analyses, stating the condition of the pipe at the point where each sample was taken. He found the main constituents of the soil to be "quartz sand, clay and iron oxide in varying proportions." He also found by experiments with samples of steel from the pipe

(1) Rusting takes place in comparatively pure water containing little oxygen and carbonic acid.

(2) **That the amount of rust formed is nearly double in the presence of a little common salt, sodium carbonate or a mixture of magnesium chloride and sodium nitrate;** whilst it is considerably increased in the presence of a little calcium carbonate, chloride or sulphate, magnesium sulphate, sodium sulphate or nitrate. All these salts occur in the soils examined.

(3) Water extracts of three soils where the pipes were said to be very bad yielded nearly double the amount of rust yielded by pure water.

Mr. Simpson's conclusions drawn from this set of soil analyses given in his report of June 6, 1906, were:

This table shows that the whole of the soils examined contained soluble salts varying in amount from 0.1 to 1.33%. Corrosion more or less intense is therefore to be expected at all the points from which the samples were taken. This corrosion will be entirely prevented by the asphaltic covering where intact. Wherever it is chipped or scratched the pipe will be open to attack.

The attack will vary with the moisture of the soil, the quantity and nature of the soluble salts in the soil ("chlorides, sulphates and nitrates may be expected to have the most effect"), and the attack will increase with "lack of homogeneity of the steel."

In Mr. Simpson's report of Sept. 12, 1906, the

*Elsewhere in the report Mr. Reynoldson says: "It appears from my own personal observations and from all other evidence obtainable that the tubercles reach a maximum growth when they have attained a depth of from 1 to 1½ ins."

chief further comment on the effect of the soil on the pipe was as follows:

The life of steel pipes is very considerably shortened where the soil in which they are laid contains over 0.1% of soluble salts, such as common salt, gypsum (calcium sulphate), etc.

CHARACTER OF WATER CARRIED BY THE CONDUIT.—There seems to be a general agreement throughout the reports that the properties of the river water carried by the conduit were such as to cause it to attack the steel wherever the coating had failed or been damaged. As the report contains no single exposition of the character of this water in relation to corrosion we bring together here various scattered references.

Mr. E. S. Hume, Chief Mechanical Engineer, Western Australia Railways, in two reports on the use of reagents to prevent corrosion in locomotive boilers from this and other Western Australia waters testifies to the bad character of the Coolgardie supply as regards corrosive effects. Commenting on analyses of sludge and scale from a boiler which had been supplied with water from the Coolgardie main he said:

It was then clear to me that some special action should be taken to deal with the corrosive body in [this] water, viz., magnesium chloride, which is present to the extent of nearly three grains per [Imp.] gal.

Three analyses of this water accompanied Mr. Hume's report, as follows:

	Grains per Imp. gal.		
	Mar. '07	—June, '08—	
Alkaline chlorides or sodium	11.9	13.3	13.3
Magnesium chloride	2.32	2.98	2.32
Magnesium carbonate	.237	.14	.72
Calcium sulphate	.987	trace	trace
Calcium carbonate	.59	1.25	1.5
Iron oxide and alumina	.21	.14	.28
Silica	.42	.28	.49
Organic matter	5.12	2.91	2.39
Total solids	21.7	21.0	21.0
Total hardness, degrees	4.0	4.5	4.8
Temporary hardness, degrees	.9	1.4	2.4

The samples in the first and third columns were from different stations; origin of other sample not stated.—Ed.

Mr. Reynoldson states in one of his reports that the Coolgardie supply contains more chloride of sodium

than the water supplied to cities and towns generally. This salt is, on the electrolysis theory, considered to be one of the most active agents of corrosion.

Mr. Mann, in his reports, suggests that the corrosive quality of the water may be due

not so much to the high proportion of corrosive salts, as to the absence of protective "hardness."

Another explanation offered by Mr. Mann is:

The carbonic acid gas in the air (4 parts per 10,000) is the principal agent in all the rusting of iron which takes place under ordinary atmospheric conditions. When air is dissolved in water this carbonic acid gas also passes into solution so that any water collected on the surface catchment, and therefore necessarily having a considerable proportion of air dissolved in it, also carries with it a certain amount of carbonic acid. The amount of air which will be dissolved by water varies of course with the pressure and temperature, and under the working heads found in the Goldfields Water Scheme main a very considerable amount of air (and especially of its carbonic acid) must be held in solution by the water. Mr. Reynoldson has indeed informed me that at times the water issues from the pipes quite milky in appearance from the bubbles of liberated gas which are set free with the diminution in pressure.

In the report of the British experts (mentioned more specifically later on) analyses are given of water taken from (1) the impounding reservoir, (2) tank at Pumping Station No. 4 and (3) Mt. Charlotte Service Reservoir, Kalgoorlie, at the very end of the conduit, as follows:

PARTS PER 100,000.

	(1)	(2)	(3)
Sodium chloride	25.71	25.39	25.49
Magnesium chloride	5.15	5.54	5.46
Calcium sulphate	2.31	2.31	2.17
Calcium carbonate	0.57	0.66	0.78
Magnesium carbonate	1.37	1.03	0.99
Silica	0.28	0.34	0.38
Iron oxide	0.02	0.04	0.02
Mineral solids	35.41	35.31	35.29
Free carbonic acid (CO_2)	0.88	0.75	0.68
Combined acid (CO_2)	1.20	1.05	1.29

Commenting on these figures the experts say:

The supply is characterized by its containing a somewhat considerable proportion of sodium chloride and of magnesium chloride, while carbonates are present in minute quantity only. The free carbonic acid present is also small. It is to be expected that such a water should possess a more than usual corrosive action upon iron, and we found by direct experiment that it rusted steel more vigorously than London water, which contains 8.9 parts of combined carbonic acid, the relative activity upon steel being in the proportion of 2.38 to 1.72.

THEORIES OF CORROSION.—The reports of both Messrs. Simpson and Mann, already mentioned repeatedly, review various theories of corrosion, particularly the electrolytic theory, which is accepted by each. On the lack of homogeneity of steel in and its relation to corrosion Mr. Simpson says:

In the case of mild steel of the nature used in these pipes the internal structure is found to be a main mass of "Ferrite" which is almost chemically pure iron, and embedded in this mass numerous small grains of "Cementite," a carbide of iron (Fe_3C), more or less regularly distributed In these two constituents of the steel plates we have the necessary poles and connections to form, when in contact with a solution of an electrolyte, a series of small batteries, each causing corrosion.

Ferrite is a highly electropositive substance and therefore dissolved with comparative rapidity. Cementite is more electronegative, and being also the cathode is but little affected by the action.

Mr. Mann concluded:

That the cause of the corrosion is electrolytic action accelerated by the presence of acid salts dissolved in the water, by carbonic acid dissolved from the air, and by the absence of basic salts, especially those of lime generally occurring in waters in the form of temporary hardness.

That the corrosion has appeared much sooner and in a more serious form than might have been expected through imperfections in the coating.

There is not sufficient evidence to show whether the composition of the steel employed has been an important factor, but this point should not be ignored in considering the stability of iron structures.

The British experts (named further on) stated:

Electrical experiments led us to the conclusion that the essential cause of the corrosive properties on steel or iron of all waters is the dissolved oxygen which they contain. On removal of this oxygen the electrical action ceases.

Corrosion in Other Australian Pipe Lines.

As throwing light on the subject the reports of the Western Australian officials make reference to corrosion in other Australian pipe lines, cast iron as well as steel.

Mr. Reynoldson gives data furnished him by Mr. Faulkner, Superintending Engineer of the Metropolitan Water Works Board, Perth, regarding a 21-in. riveted-steel main from Victoria Reservoir and also regarding a 12-in. cast-iron main, apparently leading from the same reservoir. The steel main had been in service since October, 1897, or 11 years. Tests of carrying capacity showed "it to be very little less than that of a new pipe of the same size and construction." Examination at a number of points showed the interior of the steel main to be in good condition, "and in very much better condition than the majority of the pipes examined on our 30-in. main"—a fact which Mr. Reynoldson was unable to explain.

The 12-in. cast-iron main, laid in 1890, or 18 years before, "conveys hill water only" [evidently a corrosive water] in its upper portion, but below it carries bore [well] water and hill water after treatment with lime. Five years ago a scraper was passed through this main. On opening up a piece of the pipe which carries hill water it was found that

the pipe was completely encrusted with tubercles to a thickness varying from a minimum of about 1 in. to a maximum of about 1½ ins. . . . The whole surface of the metal under the tubercles, although retaining its original shape, had been converted to a depth of nearly ¼-in. to a substance of the resemblance and softness of plumbago. There is practically no tenacity in this material, and the strength of the pipe is consequently reduced by the extent of the decay of the metal.

In two sections of the cast-iron pipe on the lower reaches, the tuberculation of the pipe was not so extensive in either area or depth, nor was the affected metal so soft as in the case of the upper section.

Mr. Mann gives further and later information regarding this same (Perth) cast-iron main. The main was scraped the second time in 1908, or five years after the first scraping. This resulted in the removal of as much material as at the earlier scraping, showing as much tuberculation in five as in the previous 13 years [assuming that the second scraping removed nothing left by the first]. Speaking of the tubercles and of his studies of this cast-iron pipe in general Mr. Mann says:

When such a tubercle is removed from the interior of the pipe it leaves what is apparently an unaffected metallic surface which gives rise to the impression that no corrosion has occurred, but this conclusion is easily seen to be illusory. The pseudo-metallic surface was found to be soft, could be cut into with a knife, and on working it with a sharp chisel a soft black pulverulent mass was removed, extending to a depth of about 3/16-in. down to the true metallic surface, which was then found to be extensively and irregularly corroded.

When this black spongy mass was removed, to my great surprise, it was found that it heated on exposure to the air, and became so hot that moisture was driven off from it in the form of steam. It was strongly magnetic and was found on analysis to have the following composition:

Water	13.42
Silicon	4.98
Iron (metallic)	19.30
Ferric oxide	52.42
Carbon	9.48
Sulphur	0.45
	100.06

Calculating the silicon as silica this would be 10.68, and the oxidized iron as ferrous oxide the latter would be 47.19. It is stated that both the iron and silicon probably "exist partially in each form."

The composition of the nodules was as follows:

Moisture	4.12
Water of hydration	11.34
Silica	2.20
Sulphur	0.76
Carbon	1.05
Ferric oxide	73.53
Magnetic oxide	6.54
Alumina	0.39
Manganese	trace
	99.93

Mr. Mann's comments on the figures just given and his final remarks on the corrosion of the Perth cast-iron pipe are as follows:

(1) The material is attracted by a magnet due to the presence of magnetic oxide.

(2) **There is an absence of alumina such as would be present if the nodules were partly formed by sedimentation from clayey matters originally in suspension in the water, and the small proportion of silica indicates the absence of sand from a similar source.**

The presence of magnetic oxide alone does not throw special light on the origin of the substance as there is evidence that some of the ironstone gravel surrounding the reservoir possesses magnetic properties, but in the absence of other evidences of sedimentation the presence of magnetic oxide in the nodules indicates that it has been formed by corrosion of the iron pipe.

The conclusion arrived at as the result of this examination of the Perth pipe was that the nodular formation was entirely due to the corrosion of the metal of the pipe itself, the iron being dissolved out and then by subsequent oxidation being converted into accumulations of hydrated oxide, which forms the mass of the tubercles.

The cause of the corrosion, judging by the result of the analyses and by analogy with similar cases which have been recorded in many parts of the world, is electrochemical, due to the action upon the ingredients of the iron of the water flowing through the pipes accelerated and increased by the salts dissolved therein.

Reverting to the Perth 12-in. cast-iron main later in his report, when discussing electrolytic corrosion, Mr. Mann says it was long thought that cast-iron was more resistant than steel, but the graphitic layer in corroded cast-iron pipes has served

in many cases to conceal the real state of affairs, hiding the fact that the metal was deeply corroded when it was apparently unattacked. Steel has only been used for a comparatively short number of years in works of this description, and therefore reliable comparisons cannot be drawn; in fact the question of which metal should be used works out to one of cost . . . [including] the enormous expense of carriage such as would have been incurred by the use of cast-iron pipes on the Coolgardie Water Scheme.

There may be inserted here a remark on the relative corrosion of iron in steel in one of the two already-mentioned reports of Mr. Hume. Commenting on some experiments reported on p 330 of London "Engineering" for March 13, 1908, Mr. Hume says:

It would appear from these experiments and the result obtained from cast-iron in Germany that mild steel may now be considered as correct a material to use for the manufacture of water mains as when the main pipe line of the G. W. S. [Coolgardie] was put down.

The Method Adopted to Combat External Corrosion.

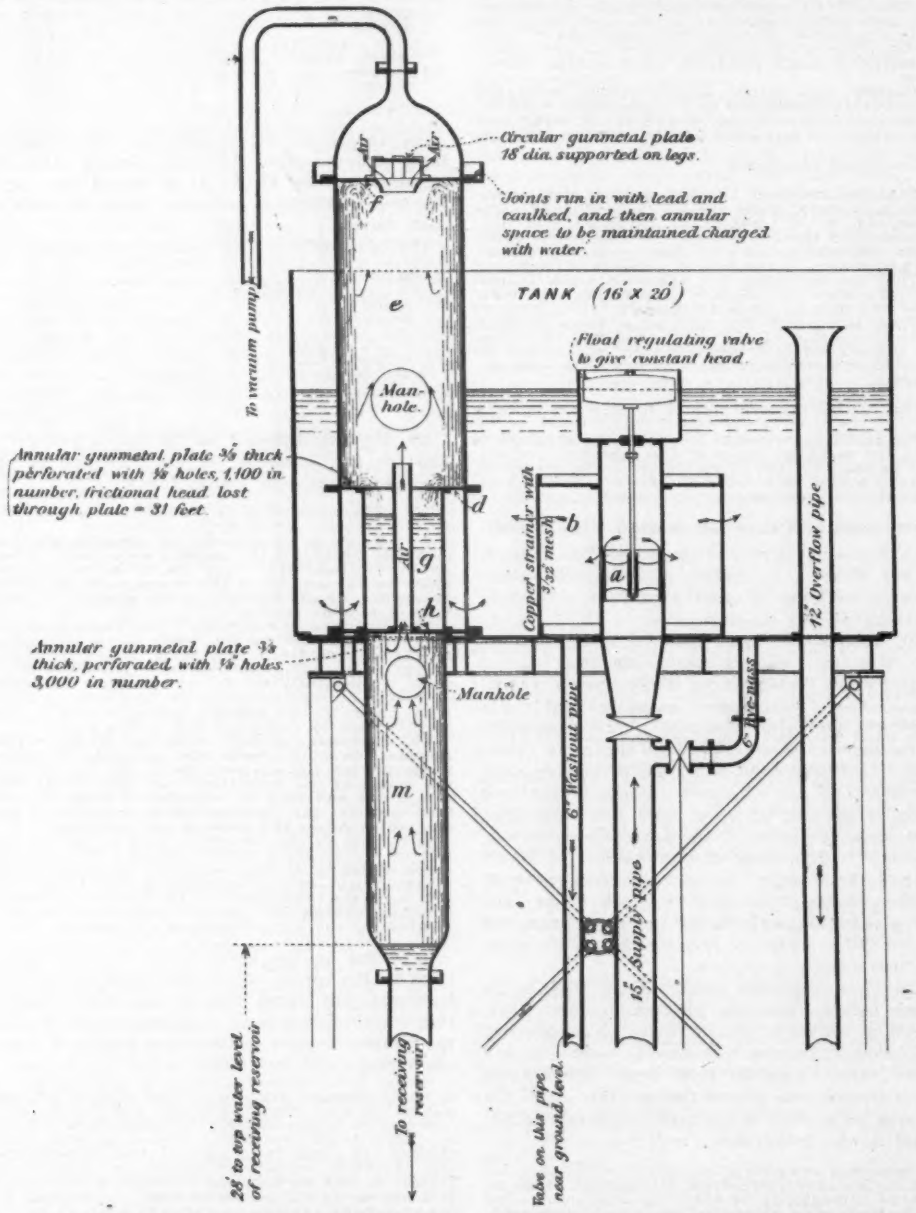
Mr. Reynoldson's report of Nov. 24, 1908, describes the method employed to prevent external corrosion as soon as need for action was realized. This was subsequently adopted as a permanent

or continuous measure, except for the adoption of a recommendation of the British experts that where the pipe exposed for re-coating was recovered it should be laid on a cradle of lime concrete as an additional protection against external corrosion. Quoting now from the report by Mr. Reynoldson just mentioned:

Following the preliminary examination, a thorough special examination of the main throughout its entire length was put in hand. Two complete lengths of pipe at all depressions and in all classes of soil were uncovered for their full length, and wherever active pitting was revealed the pipe was further opened up in both directions therefrom until found to be in good condition.

[Elsewhere in the report Mr. Reynoldson states that the coating was composed of "one part of bitumen to one of coal tar applied boiling hot, care being taken that the metal of the pipe is thoroughly dry before the coating is applied. Several other trade protective coatings have been used on short sections, but some of these perished in a few months; others are palpably decaying and the best are not nearly so good as the bitumen and tar composition."]

In the majority of cases and wherever possible, the pipe is left exposed, resting on cross timber bearers, between which the earth is removed from under the invert of the pipe, for the purpose of keeping the pipe completely clear of contact with the earth. The sides of the trench are given slight slope to prevent subsequent caving in. Although it may not be advisable to leave long lengths of piping exposed, it is considered that this can be safely done on the comparatively short continuous lengths so far met with, as the water, while traversing the short sections, is not raised materially in temperature, and consequently very little contraction or expansion in the pipe results.


Circular gunmetal plate 18" dia. supported on legs.
Joints run in with lead and caulked, and then annular space to be maintained charged with water.
To vacuum pump.
TANK (16' x 20')
Float regulating valve to give constant head.
Man-hole.
Annular gunmetal plate ⅜" thick perforated with ⅛" holes, 1,100 in number, frictional head lost through plate = 31 feet.
Copper strainer with 3/32" mesh.
12" Overflow pipe
Annular gunmetal plate ⅜" thick, perforated with ⅛" holes 3,000 in number.
Manhole
6" Waste pipe
6" Washout pipe
15" Supply pipe
28' to top water level of receiving reservoir
To receiving reservoir
Valve on this pipe near ground level.

DE-AERATING APPARATUS TENTATIVELY SUGGESTED BY BRITISH EXPERTS TO STOP INTERIOR CORROSION OF COOLGARDIE STEEL PIPE LINE.

By this method it is believed that the bulk of the bad places have been located, although experience shows that there are occasional zones which have escaped detection. Fortunately, however, the pitting is found to be confined to isolated places on the pipe in the bad zones, and the pipe can be saved even after rust-holes have been discovered. In sand plain, iron-stone gravel, and non-retentive soils generally, the metal is found to be in good order, irrespective of the condition of the coating, and it is only in depressions and basins where the soil is retentive of moisture that the metal is attacked seriously.

After locating the bad zones and removing the earth cover, the old coating is completely scraped off and the pipe re-coated with a mixture of bitumen and tar, which are, experience has proved, to be the best field composition for this purpose.

It is considered that the methods of combating external corrosion are superior to those practiced, or generally possible, elsewhere and are effective.

Perhaps it should be added that Mr. Simpson stated that continual renewing of the external coating would be necessary and that he also laid great stress upon the reduction of leakage to a minimum, the diversion of surface water from the pipe, and local drainage wherever necessary to facilitate the drying of the soil after rainfalls.

Methods of Combating Internal Corrosion.

As the studies of the problem progressed it seems to have become apparent to all engaged in them that the water must be treated in some way to prevent corrosion. This was urged by Mr. Hume (verbally and in a report of Aug. 12, 1908), both as a means of preserving the pipe and its carrying capacity and of making the water fit for use in the locomotive boilers under his care. Mr. Hume's suggestion was renewed, with additional supporting evidence, in a report dated Jan. 20, 1909.

Mr. Mann, in a report dated Nov. 25, 1908, said:

That the most feasible method of dealing with the rusting trouble seems to be to increase the protective basic substances in the water by the addition of lime in the proportion of about 25 [Imp.] grains per gallon of water in the main, and that similar additions be made from time to time as control experiments may indicate to be necessary.

Various methods to prevent internal corrosion were considered by Mr. Reynoldson, who it will be remembered is the Chief Engineer of the Goldfields Scheme, in his report of Nov. 24, 1908. After dismissing internal scraping (to restore the carrying capacity) as likely to "renew the activity of the corrosion, and shorten the life of the main," and after showing how costly it would be to take up, re-coat and relay the main (which might extend the useful life of the pipe 25 years from date), he dismissed scraping as worthy of consideration only as a last resort, and said that even though re-coating should prove to be a little cheaper and more effective than he anticipated, yet he considered that

it would be unwise to carry out such an expensive maintenance work before the question of the cause and prevention of the corrosive action of the Mundaring water [Coolgardie supply] has been completely investigated.

Mr. Reynoldson then took up the possibility of lime treatment, as follows:

It is a common practice to heat water for the prevention of corrosion of boilers, but, to the best of my knowledge, it has never to the present ever been attempted to prevent the corrosion of water mains by water treatment. This method of corrosion is, however, I consider, worthy of the most exhaustive investigation.

From the published data available, it appears that pipes carrying waters which deposit calcium carbonate on the pipe do not corrode. This fact suggests heating the water with lime before its entry into the pipes.

Experiments have been made at this office which, however, indicate conclusively that the addition of even a considerable amount of lime (up to 18 grains per [Imp.] gallon) to the **air-charged** water, as pumped in the Coolgardie main, is not, in itself, a sufficient guard against corrosion.

Evidently Mr. Reynoldson had not yet been informed of the substance of Mr. Mann's report of the following day, already quoted, in which the latter recommended treatment with 25 grains of lime per Imperial gallon.

Mr. Reynoldson seems to have been impressed with the claims of the Metal Protection Co., of Melbourne, proprietors of the "Cumberland Metal Protection Process," an "electrolytic process for the prevention of corrosion of boilers." Considerable space is given to the claims for this process, both by Mr. Reynoldson and in later reports supplementary to the final report of the government board (mentioned again later), but the company was unable to give satisfactory assurances of the applicability of its process to a pipe line, and provisional cost estimates, indicated that it would be highly expensive. These estimates were submitted by Mr. W. J. Hancock, Government Electrical Engineer, in a report dated May 24, 1910. Mr. Hancock stated that, as applied to boilers,

This process may be briefly described as consisting of fixing an electrode in the form of a rod into a steam boiler and maintaining a constant supply of electricity at low voltage through the rod and water, and thus forming by electrolytic reaction a protective film on the inner surface of the boiler and tubes.

REPORT OF BRITISH EXPERTS.—In his report of Nov. 24, 1908, Mr. Reynoldson renewed a former recommendation for the employment of "the ablest European Specialist" to study the corrosion problem. The late George F. Deacon, of England, was engaged for this purpose early in 1909, and on his request that there be associated with him "some eminent analytical chemist," Sir Wm. Ramsay and Mr. Otto Hebner were also engaged. After Mr. Deacon's death, his place was taken by the firm of Sir Alexander Binnie, Son & Deacon. On Sept. 30, 1909, the British experts submitted their report.

Nearly the whole of the report deals with interior corrosion. Of the other subjects treated, some have already been mentioned and others will yet be referred to in this article.

Taking into account chemical and electrical theories of corrosion, and in the light of their own experiments, the British experts concluded that

> if the oxygen of the contained air [air in the water] can be removed, corrosion will be arrested, . . . and when the air is once removed steps should be taken to prevent its re-entering the water.

The addition of ferrous sulphate and an alkali to the water, "charging the water with ferrous carbonate by filtering it after it had been carbonated, through vessels containing metallic iron," and boiling were considered as three possible means of removing the oxygen. In connection with an experiment on the effect of boiling a partial vacuum was used to cause the water to boil at a lower temperature. The report continues:

> At this stage it struck us that much simplification would be introduced if no attempt were made to heat the water, but if it were allowed to pass into a vacuum in a finally [finely?] divided state, at the ordinary temperature. An experiment was therefore made at 17° C. (62.6° F.) in which the vacuum was kept perfect, except for the pressure of water-vapor at 17° C.; which pressure is only 18 mm., or 0.72-in. of mercury. The dissolved oxygen was reduced from 6.5 to 1.4 c.c. per litre.

The experts expressed the belief that a perfected large-scale apparatus would give even better results, by giving better spray and vacuum, and submitted opinions, based partly on experiments, in favor of this process over chemical treatment. Acting on this belief they recommended the removal of the air contained in the water "by spraying the water into a vacuum" and adding to the water "about 3 grains of lime per [Imp.] gal., which quantity may be reduced if the water when delivered is found to be alkaline.

The report is accompanied by a sketch of such a de-aerating apparatus, which we reproduce on the opposite page, together with the descriptive text:

> The water to be treated is fed into an elevated tank through an equilibrium valve "(a)" controlled by a float so as to keep the level constant. On entering the tank the water passes through a wire gauze screen "(b)" of 3/32-in. mesh to remove any suspended matter liable to choke the orifices to be presently described. The water passes upwards from this tank through the annular gun-metal plate "(d)" into the vacuum chamber "(e)" connected with the air pump suction "(l)". It is assumed in the sketch, that the vacuum is equal to 28 ft. of water. As the plate "(d)" is shown 3 ft. below the level of the water in the elevated tank, there would be a pressure equivalent to 31 ft. of water on the orifices. These orifices are assumed to be ⅛-in. diameter, and would be about 1,400 in number, making due allowance for certain of them being blocked. Springing upwards, the jets impinge on the annular gun-metal plate "(f)", and the water, on falling back, is collected in the annular vessel "(g)" surrounding a pipe open at both ends, and connecting two vacuum chambers. The annular plate "(h)" is perforated with 3,000 ⅛-in. holes at about ¾-in. c. to c., through which the water would descend in fine streams, the velocity of which would be such as to prevent coalescence should they touch one another. After falling through a second vacuum chamber "(m)", the water is discharged into a pipe communicating with a regulating reservoir, the level of the water in the pipe being kept 28 ft. above the level of the water in the reservoir by means of the assumed vacuum. The pump suctions are taken from the reservoir, the side walls of which should be vertical, and on the surface of the water should float a timber raft or other device, which, while responding to the level of the water in the reservoir, would largely prevent the access of air.

The lime referred to above should be added as milk of lime to the reservoir into which the de-aerating apparatus discharges, by means of a pipe delivering below water level, and the reservoir should be divided into two compartments containing about 1,200,000 [U. S.] gals. each so that one can be cleaned out while the other is in use. In these compartments such portion of the "milk of lime" as had not passed into solution would be deposited. The floor of the compartments should fall to the mouth of a washout pipe and should be covered with a system of perforated pipes connected with a high-pressure water-supply so that the settled sludge can be agitated and held in suspension when the compartment is emptied for cleaning purposes. It is possible that the water as delivered to the consumers may taste flat owing to the absence of air, or perhaps, of iron due to the nodular incrustations now formed passing into solution.

Whether this should prove to be the case or not the water can be easily re-aerated, and the iron in solution re-deposited, by allowing it to fall through a tower filled with large pieces of hard coke.

The report of the British experts contains recommendations for preventing the water from being recharged with air after it was de-aerated. These involve changes in piping arrangements at the receiving and suction reservoirs located at the several pumping stations, tanks at summit levels in the pipe line so as to keep the pipe fully charged with water throughout and thus exclude air, and other changes which are chiefly local in character.

REPORT OF THE WESTERN AUSTRALIAN DEPARTMENTAL BOARD.—In January, 1910, the Cabinet referred the report just reviewed to a departmental board for advice. This board was composed of Mr. James Thompson, M. Inst. C. E., Engineer-in-Chief, Public Works, and Messrs. Hume, Mann and Reynoldson, already mentioned many times. The board reported on May 31, 1910. It advised against de-aeration, with the heavy expense for "completely excluding air from the main, and the uncertainty of the efficacy" of the process, and recommended that

> a lime treatment by itself, using 5 grains per [Imp.] gal., should, in the first instance, be tried, and so arranged that it could be supplemented by de-aeration, if found necessary.

The board also recommended the construction of various reservoirs, changes in piping, etc., partly to aid in the exclusion of air and partly for general reinforcement of the system, particularly as regards storage. In addition, the board advised the insertion of by-passes on the conduit at 20-mile intervals, "for the purpose of determining the efficacy of the treatment at critical points throughout the whole length of the main."

The cost of a 1,200,000-gal. (U. S.) lime treatment tank and settling reservoir was estimated at £6,000 (under $30,000) against £7,000 for de-aeration apparatus and £10,000 for lime-treatment plant estimated by the British experts, but the estimate was for plants to treat 6,000,000 (U. S.) gals. per day. Other works recommended by the British experts brought their total estimate to £187,000, against £31,000 for the total of estimates for the works advised by the governmental board—of course for less work.

The annual working expenses for treating 3,600,000 U. S. gals. per day by the local plan were placed at £1,700 (about $8,200).

A number of appendixes accompanied the report of the departmental board, bearing upon one phase or another of the corrosion problem. Considerable of the space of these appendixes was devoted to the favorable results obtained by applying lime to the water which had passed through the Coolgardie main before it entered a branch from the lower end known as the Kanowna main. After an experience of over a year with line treatment, it was found that the corrosion and also the perforations of this main were materially reduced, and that a coating of carbonate of lime had formed on the interior of the pipe. The water appeared to contain much less carbonic acid than had been supposed, so that to increase the deposit and "at the same time remove the free lime from the water which would, doubtless, have a constipating effect on the consumers," Mr. Mann suggested the introduction of "large volumes of air at various points" into the main "by means of water-jet injectors operated by the current in the main itself." Mr. Reynoldson took up this suggestion, but found it would be not only prohibitive as to cost but also impracticable.

DIFFERENCES OF OPINION BETWEEN THE BRITISH EXPERTS AND THE WESTERN AUSTRALIAN DEPARTMENTAL BOARD.—As we have seen, the British experts attributed the internal corrosion to oxygen in the water. The departmental board accepted, instead, the opinion of Mr. Mann that the attack on the steel was due to hydrogen. Mr. Mann himself stated, in one of his appendixes, that the experience with lime treatment (Kanowna main)

> must far outweigh the result of any number of laboratory experiments, and I think affords a conclusive proof of my view that the cause of the corrosion is attack by hydrogen, and not by oxygen, and that if the hydrogen attack is stopped by hydroxyl ions introduced through the agency of alkali there is no necessity to exclude the air, or to pay any attention to the secondary attack of the oxygen which may be present.

The presence of air might indeed be advantageous, by aiding the formation of the protective coating, and eventually this coating might become so effective as to make the lime treatment no longer necessary.

The British experts laid much of the corrosion of the Coolgardie main to the fact that the advice of an earlier British Commission had not been followed. Prior to constructing the main, this earlier Commission had advised a double coating of the pipe in "boiling asphalt" (two dippings) and that the pipe be laid entirely above ground. The departmental board pointed out in its report that when double dipping was advised it was supposed that the pipe would be made in England, dipped there, and re-dipped in Australia, but the plates were imported and then the pipe was made in Australia. Had the pipe been imported the local board believed that two coatings would have been advisable, but under the circumstances they think the extra expense of a portable plant for re-dipping just before laying would have been unwarranted. They also uphold the burial of the pipe, but in valleys and moisture-retentive grounds they believe a less deep coating would have been better, with side drains as needed.

In conclusion, it may be noted that in July, 1910, the Government decided to adopt the recommendations of the departmental board, and that on July 15, 1910, the date of Mr. Reynoldson's preparatory notes to the series of reports under review, the works advised were being carried out.

Six Gas-Electric Motor Cars will be placed in operation by the St. Louis & San Francisco R. R. for various light services. These cars are of steel, 70 ft. long and 10 ft. wide over sills, with a turtle-back roof, pointed front, observation rear and center doors. The interior arrangements are adapted to Southern traffic conditions, having separate compartments and entrances for negro and white passengers, and for baggage, etc. The seating capacity of a car is for 55 persons. The car is electric lighted and heated by the engine-jacket cooling water or a separately-fired coal-burner. The power-generating plant is located in the front of the car and comprises (1) a main set consisting of an eight-cylinder gasoline engine with direct-connected generator and (2) an auxiliary set consisting of a three-cylinder gasoline engine driving a small generator and having one cylinder fitted as an air compressor. The air is used for brakes, sanders, bell, etc., and for starting the main unit. The auxiliary generator furnishes current for lighting and various services. There are two 100-HP. standard railway motors, driving the two axles of the forward truck and taking current from the main generator through an ordinary street-car controller. The car has straight and automatic air and auxiliary hand brakes.

Gravel as Ballast for Railway Track.*

Owing to its high cost, hard crushed stone can be afforded only for ballast in roadbeds which are heavily taxed with traffic, while stretches taxed to a less extent must resort to material near at hand, mostly river or mountain gravel. Still, increasing speed and weight of rolling stock on these latter stretches are making heavier demands upon the ballast, principally in the direction of greater resistance to change of position of the rails.

The greater carrying capacity of crushed stone is due principally to the many sharp edges of the individual pieces. This gives it the high resistance when used as ballast, which is not greatly reduced under shock. On the other hand, the gravel pieces give way easily under pressure and lose still further in resistance when subjected to shock. These different characteristics of crushed stone and gravel affect the roadbed as to (1) the cross-sectional shape of the ballast, (2) the support to be given the track, and (3) the shape and spacing of the ties. The object of this article is to determine to what extent gravel makes possible a uniform and permanent roadbed.

It was desirable to follow out the changes in different individual roadbed stretches and note their greater or lesser durability in comparison with the peculiar characteristics of the ballast of each stretch. The ballast of the observed stretches consisted of a mixture of coarse and fine gravel with a sand content of 25 to 33%, consisting of grains under 1 mm. greatest diameter. The ties were spaced 30 to 33.6 ins. The traffic yearly amounted to about 1,200,000 tons. Among the daily trains were several which had a velocity of 46½ m.p.h. and more.

The observations were continued two years; the elevation of the rails was taken every two months, and during affecting weather conditions more often. It was determined that the most important observations came just previous to the occurrence of frost, during the time of the heaviest frost, and just after the complete disappearance of frost. The rail elevations at the above mentioned times are shown [parts only of the diagrams are given as examples in Fig. 1. Ed.] The horizontal base line indicates the first observed condition during the autumn, the lines II, III and IV the altered elevations during the severest time of winter, of spring, and of the following fall, respectively. Under each group of observations is a longitudinal section through the track which illustrates the composition of the ballast and sub-soil and the depth of the frost line. The changes observed for the first year and for the second were so similar that the observations for one year only are given.

Close relations exist between the different elevations of the rails and the nature of the soil of the roadbed. Every clay and clay-bearing soil drove the track upward, and (as other observations indicated) also towards the sides. The more uniform such soil is, and the more uniformly it is distributed, the more uniform is the tendency to lift the track and to lower it again after the disappearance of frost.

Irregular mixtures of sand and clay, such as occur in earth embankments, led to very unfavorable action in spots, owing to the fact that the earth, due to the action of the frost, was unevenly forced upward and outward and did not regain its original position after frost had disappeared. Clean and evenly fine grained sand proved to be quite constant under the action of frost, and a similar absence of the expansive force of frost was noted in the gravel ballast itself, though it was not entirely free from earthy constituents.

During the seasons of no frost such apparent influences of the soil underneath the ballast were not noted. In the summer, the sinking of the rails was generally very small and hardly measureable. Several times notice was taken of the rising of the rails up to 0.8-in., but only at the hottest time of the year.

In order to illustrate more clearly the changes taking place in the rail surfaces in relation to the seasons and the condition of the sub-soils, cross-sectional views illustrating the sinking and rising of distinct groups of the stretches under observation in continuous line for two years are given at the right of the diagram.

Of all the changing lines, those of A and A-1, Fig. 1, (between the points 13 to 18), are of particular importance. The rails and ties here rest on a strong gravel bed, under which clean sharp sand extends to a level lower than the frost line. The ties are spaced 30 ins. and the rails are fastened to them with screw-spikes. The extraordinary permanence and uniform position of this piece of track indicates that gravel containing a large proportion of sand will act as very serviceable ballast under proper conditions of subsoil and track construction.

The recent track construction with heavy rails and narrow tie spacing is well adapted to distribute the load over a greater portion of the ballast, and thereby decrease the demands made on the ballast. On the other hand, it makes increased demands for more regular construction and the prevention of all local disturbances of the roadbed. The nature of the ballast, whether crushed stone or gravel, does not assist in remedying the influences of the soil upon which the ballast rests. In order, therefore, that the subsoil have no influence on the roadbed, it is necessary that it consist of a material which is constant under the action of frost, and extends below the frost line. Any bed of clean sand will serve as a frostproof sub-soil even when the sand is of fine grains. When the transforming influences of the sub-soil and the weather are removed, the characteristics of the ballast itself come into play.

If the loads are unequal which are transmitted to the ballast through the ties, then the set underneath the more heavily loaded ties is more serious than in the others. Consequently, the original conditions of loading of the ballast are gradually changed, principally in that the pressures under the more heavily loaded ties gradually diminish and the pressures under the lightly loaded ties gradually increase, until the condition of loading becomes quite uniform. In order to observe these phenomena, a section of roadbed was purposely tamped unevenly, so that a portion of the ties rested solidly on the ballast, while the other portion was without any support. By repeated observations it was found that the spaces between the ballast and the ties gradually diminished, and after six months disappeared entirely.

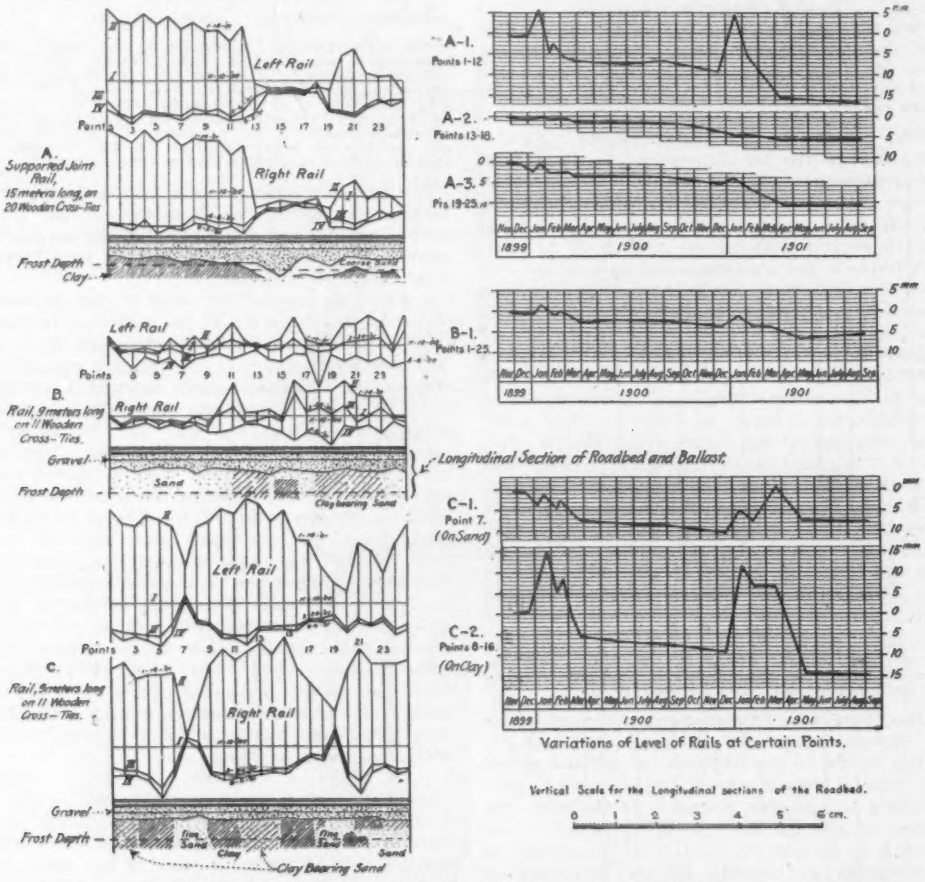


FIG. 1. DIAGRAMS SHOWING VERTICAL MOVEMENTS OF TRACK DUE TO HEAVING AND SETTLING OF ROADBED IN DIFFERENT KINDS OF SOIL.

(Each set of left-hand diagrams shows three observations on each rail and gives a section of the roadbed and ballast. The right hand diagrams show the variations in level of individual points on the rails for a period of about two years.)

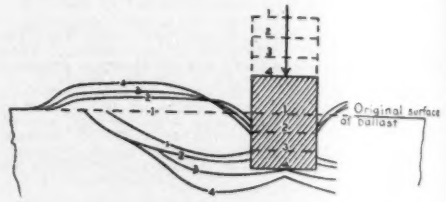


Fig. 2. Displacement of Sand Ballast Under a Tie Subjected to Load (Model Test).

The continual changing of the form of the roadbed is a result partly of the compression of the ballast, and also, perhaps to a larger extent, the result of a sidewise spreading. The loading of the bed under and adjacent to the ties is so continually varying that an equalization of the pressure cannot take place, and the lightly loaded part between the ties is continually being displaced by the heavily loaded part beneath the ties. [This movement has been studied by Dr. Zimmerman by means of experiments on a small scale, Mr. Braüning refers to these in the following statements.—Ed.]

After the sand was entirely compressed by the

*Abstract of a paper by Mr. C. Braüning, published in the "Zeitschrift fur Bauwesen" (Berlin) in 1904. Our abstract is from a translation given in Bulletin 136 (June, 1911) of the American Railway Engineering Association, having been made for the committees on Ballast and Roadway. Elsewhere in this issue will be found a paper on stone ballast and an editorial discussion of the general subject of railway ballasting.—Ed.

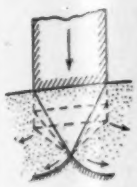


Fig. 3.

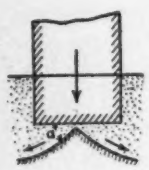


Fig. 4.

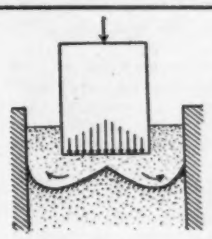


Fig. 5.

FIGS. 3, 4 AND 5. DISPLACEMENT OF SAND BALLAST UNDER A TIE SUBJECTED TO LOAD (MODEL TESTS).

imposed load [on a small block in a sand box having a glass side], a sidewise displacement of the sand began, first in lines which were not distinct, then becoming more distinct, until eventually very pronounced lines of separation appeared. Several of these lines are shown in Fig. 2. Although they diverge considerably in their longitudinal relation to one another, due to the variation of the internal friction, nevertheless the theoretical basic shape of the logarithmic spiral is recognizable in their curvature. The shape of the lines of separation is not changed when the ballast is piled up higher than the ties; in fact, they continue right on up to the surface.

The body of sand, which separates itself, tends

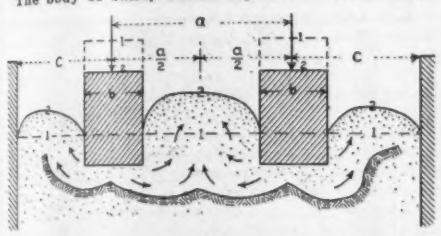


Fig. 6. Displacement of Sand Ballast Under Two Ties Loaded Simultaneously (Model Test).

to retain its original shape, and also seeks to regain the original lines of separation when the tie is forced deeper into the sand, since when this is the case resultant resistances of the sand particles sliding over one another are at a minimum (Fig. 2).

Underneath the tie the separation of the sand layers did not appear as uniformly and distinctly as above. At the start of the experiment, a slender wedge would usually form, with its apex pointing downward. This wedge would become more blunt as the tie sank deeper into the sand, and the location of the apex remained comparatively firmly fixed, so that the lines of separation, extending from the sides, retained their original position, as in Fig. 3. On the other hand, and more particularly where the sandbeds were deep and the resistances to the sidewise displacements were greater, there appeared another wedge, firmly fixed, with its apex pointing upward, from whose sides the sand particles would glide (Fig. 4). This tendency of the particles to glide from the sides of the upturned wedge continues so long as the angle "A" (Fig. 4) stays larger than the angle of repose of the material. If the bed upon which the tie is imposed is confined between two rigid walls, as in Fig. 5, the resistance of the bed with

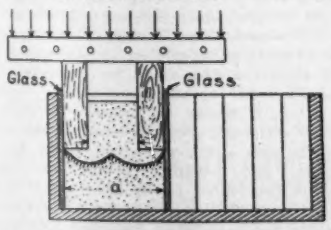


Fig. 7. Displacement of Sand Ballast Under Two Ties Loaded Simultaneously, the Ballast Being Confined at the Sides (Model Test).

these walls strongly opposes the tendency of the bed material to become displaced upwards. But if the confinement of the bed arises from the neighboring ties, simultaneously loaded, as is the case in track, moving particles which meet between the ties oppose one another, and, not finding any confining resistances, drive themselves upward. An experiment with two equally loaded ties on a confined bed is shown in Fig. 6. The distances between the ties chosen were such that the amounts of material between the ties and between the walls and the ties were equal, and thus also making the resistance in the two directions equal. This was approximately the case when a/2:c = 1:1.3. The distance between ties when the bed material ceased to rise up between them appeared to be when a = 1.5b. Even with a pressure as great as 568 lbs. per sq. in. no rising of the bed of the material was noted when the ties were closer than a = 1.5b.

Positive determinations of the action of the widths of the ties could not be made from the results [of these small-scale tests]. In order to get at the actual conditions prevailing in a roadbed, where ties are equally and simultaneously loaded, two ties were rigidly bonded together and placed in an iron box, so that each came very close to the sides of the box (Fig. 7). In order to reduce the friction of the bed material on the walls of the box, they were lined with glass. Since the three sides of each tie were contiguous to the sides of the box, the only possible escape for the bed material was between the two ties. It was observed that a wedge with its apex pointing upward appeared underneath each tie when the material between the ties had reached a certain height and the material of the bed tended to glide off the sides of this wedge, exercising a heavy pressure sidewise on the tie. The carrying capacity of the tie at its ends is less than at its center, but it increases from the ends until it reaches those points where the resistances sidewise and outward towards the ends are equal. Between these points the carrying capacity is uniform. Since the support given the tie bears a direct relation to its carrying capacity, the pressure underneath the tie on the ballast diminishes outward from the two points described above. The closer the ties are spaced, the greater the carrying capacity of the roadbed becomes, and the nearer to the ends the ties are, the points from which the pressure on the ballast decreases.

The length of the tie has no influence on the relation of the pressure at the ends of the tie, but it does affect the load intensity and the length of the uniformly loaded territory under the middle of the tie. When determining the length of the ties, consideration should be taken, on the one hand, that the bending moments do not become too great, and, on the other, that the lightly loaded portion, or portion carrying no load, is properly supported by the ballast. Since the surface of the ballast adapts itself to the elastic line of the tie, a short tie, when not loaded, will be supported at its middle, while a long tie, not loaded, will be supported at its ends. And, furthermore, the bending moment of a long tie under the rail increases considerably with its length, which should be taken into consideration with wooden ties, especially when wooden dowels are screwed in at the place of the greatest bending moment, which would considerably diminish the carrying capacity. Consideration of all those limiting features seems to determine a tie length of 9 ft.

The question of the smallest size of gravel particles and the largest admixture of foreign material permissible in gravel ballast is of considerable significance, from a practical and economical point of view, to railways depending upon gravel for ballast. The carrying capacity of gravel depends primarily on its internal resistances, which are indicated by the angle of repose of material. For ordinary dry gravel, the following values are determined:

Number.	Size of Grains.	Angle of Repose.
A	Less than 1 mm.	31° 11′
B	1 mm. to 2 mm.	33° 45′
C	2 mm. to 3.1 mm.	36° 9′
D	3.1 mm. to 4.2 mm.	37° 10′
E	4.2 mm. to 5.6 mm.	40° 15′
F	5.6 mm. to 9.2 mm.	39° 48′
G	Mixture of A, B, F = 1:1:5	34° 35′
H	Mixture of B, D = 1:1	36° 52′

Light moisture, such as is usually present at the base of the roadbed, tends to increase the adhesion between the particles, and, hence, enhances the carrying capacity of the finer grained gravel. It was found that fine-grained gravel in a moist condition had twice to four times the carrying capacity of the same gravel in a perfectly dry state; on the other hand, coarse grained gravel revealed no striking difference between the dry and the moist stage. A surplus of water, however, loosened up the adhesion of the finer grains when subjected to quick change in loading. If proper drainage is provided, then coarse-grained gravel can hardly be saturated with water; while on the other hand, fine grained gravel may easily be saturated, since it retained the water up to its point of saturation.

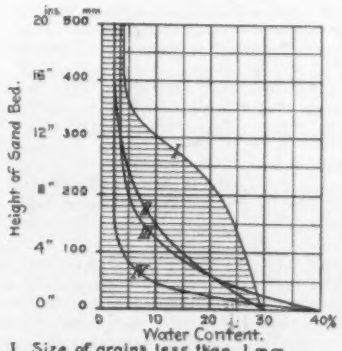
The diagram, Fig. 8, represents, by the area bounded by line I and X and Y axes, how the water content varied from the top to the bottom of a bed 20 ins. deep. The original water content of 29% decreased from the bottom towards the top to 4%. Similarly, lines II, III and IV of this same Fig. 8 illustrate the variation of the water content of different gravels made up of coarser grains as designated under the diagram. The water-absorbing capacity of the coarser gravel was greater than that of the finer gravel, but the release of water, as the level sank, was more rapid. In fact, gravel of greater than 2 mm. was practically free from moisture at a height of 130 mm. above the level of the water. The moisture finally retained after the gravel had been drained ranged with the different sizes between the narrow limits of 2.5 to 4%.

Hence, it becomes apparent that coarse gravel, though of comparatively shallow depth, readily drains itself and becomes dry; but, on the other hand, the retained water is practically the same for fine and coarse gravel, provided there is sufficient depth. The disadvantages of fine gravel in this respect may be mitigated by deepening the roadbed. Consideration must always be taken of the possibility of supersaturation of fine gravel, owing to slower draining capacity under continued rainfall. This may also occur when the roadbed begins to thaw, and the surface water, which is released first, can find no outlet into the lower layer, owing to their continuing in a frozen condition. On the other hand, there is an advantage in the tendency of the ballast to remain frozen under the ties, and so form a solid bed for them until sufficient time has elapsed for the portion of the ballast between the ties to thaw, drain to a considerable depth and become dry.

Requirements for Good Track with Gravel Ballast.

The principal requirements for a permanent and uniform roadbed with gravel ballast may be summed up as follows:

The subsoil upon which the roadbed rests should consist (to the depth of the frost line)



I Size of grains less than 1 mm.
II Pit Gravel with 25% of grains less than 1 mm.
III Size of grains 1 to 2 mm.
IV Size of grains 2 to 4 mm.

Fig. 8. Proportion of Water Contained in Sand Ballast of Different Degrees of Fineness.

of a material which is not affected by weather conditions, and when frozen does not heave upward, thus disturbing the ballast.

The continued settling of the rail bears a distinct relation to the internal resistances of the ballast. Hence, ballast, as far as it is subjected to such forces, should consist of material which is uniform in its carrying capacity. When the carrying capacity of the subsoil, therefore, is not high or varies greatly (as is the case with all earthy soils), the roadbed should be of such strength that the individual loads on the ties are evenly distributed throughout the ballast and uniformly distributed over the subsoil. Furthermore, all sidewise and circulating movements should be confined within the ballast.

In order to meet these requirements, a depth of bed about 22 ins. underneath the ties would be sufficient, provided some particularly unfavorable conditions of the subsoil do not make a greater depth necessary. A clean sand, readily permitting water to pass through it, would act well at the bottom of this bed. The actual depth of the ballast should not exceed 12 ins.

underneath the ties in order to prevent mixing with the bottom layer of sand.

In order to secure a ballast which drains readily in its upper layers, and in order to prevent the undue formation of dust underneath the following trains, and in consideration of the future increase of fine grain content due to tamping, it is desirable to prevent as much as possible the admission of fine grained particles in the ballast. This, however, only means particles less than 2 mm. in size. As a matter of fact, a mixture of fine and coarse grains is desirable, since it permits of a more solid packing of the gravel underneath the ties than when only coarse gravel is used.

But, due to the moist condition of gravel, it is not very convenient to segregate the fine particles from the coarser. In order to accomplish this separation, large coarse screens must be used. This results in a loss of a large and useful portion of the gravel, and the part remaining is often so little that the advantage gained by screening is not warranted, due to the great expense involved. Under these conditions, therefore, gravel with a 25% content of grains 1 mm. or less in size becomes practicable, as long as the conditions are not extraordinary and do not require a specially strong roadbed.

The width of roadbed bears a certain relation to the length of ties and the spacing of the ties. An extension of the ballast 12 ins. outwards from the ends of the ties (of the usual length of 8.8 to 9 ft., is sufficient.

As the height to which the ballast is packed increases, the carrying capacity of the roadbed increases. Hence, material should be piled between the ties as high as operating conditions will permit.

The width of the tie is also of considerable importance, since with constant load the unit pressures on the bed are reduced as the area of the tie increases, and the carrying capacity of the tie increases directly as its area. A general use of larger wood ties is not permissible, owing to the high purchase price and the greater difficulty of obtaining the same. It is desirable to have the ties 9 ft. in length. Strict consideration should always be given the proper and uniform spacing of ties and shaping of the roadbed in order to utilize to the limit the resistance of the roadbed.

Of greater importance than the width of the ties is the spacing of the ties. As the spacing is decreased two advantages are derived: (1), the unit pressure decreases; (2), the carrying capacity of the roadbed is increased. The limiting feature of decreasing tie-spacing is the ability to tamp the ties properly. Ties 6.4 ins. in height can still be tamped with convenience when 14 ins. apart. But this (the relation being 2.3), 24 ins. c. to c., is the lowest limit. This is the one most effective and simplest means of increasing the strength of the roadbed, and to utilize it to the fullest advantage, especially on roadbeds which are fully loaded, is urgently recommended.

THE SUPPORT OF RAIL JOINTS.—The portion of the ballast under the joints requires special consideration, since the impact at these points makes extraordinary demands on the roadbed. It has been attempted several times to strengthen this part of the ballast by packing crushed stone underneath the ties supporting the joint, but without success.

Another way, and the one usually resorted to, is to bring the two ties supporting the joint as close together as possible, 20 ins. c. to c. The closer the ties are spaced beyond this, the less is the difference between the carrying capacity of the roadbed underneath the joints and the carrying capacity of the rest of the bed. In order to further strengthen the roadbed underneath a joint, it would be effective to increase the width of the ties supporting the joint. For instance, if the width of the ties used is 12 ins., and the distance between them from edge to edge is 10 ins., then the relation between them is $550 - 300 = 1.83$, as compared with a relation of $600 - 260 = 2.31$ for the ties not underneath the joints. By means of this decrease in the distance between the ties at the joints, combined with the increased width, as well as the distribution of the load over greater surfaces, the carrying capacity of the roadbed underneath the joints is increased approximately 75%. As ties are ordinarily furnished, there is considerable variation in sizes, and there should be no difficulty in selecting a sufficient number (approximately 10%) of the proper width to arrange underneath the joints.

As a further means of distributing the shock at the rail joints, methods of combining the two ties underneath each joint by the use of a framework are being tried.

All means to increase the resistance of the ballast to impact will not be complete and sufficient to properly maintain the necessary support and steadiness of the whole roadbed as long as impacts, due to the passing traffic, at the rail joints continue to vary on account of the varying distance between rail ends, variation in the surface elevation of two abutting rails, wear of the rails and wheel flanges, and other changes in shapes which result in varying shocks. Hence, the question of a proper support for the rail joints is primarily a question of the proper joining of rails with the object of preventing low and loose joints.

Experiments on the Pennsylvania R. R. to Determine the Proper Depth of Stone Ballast and the Value of Sub-Ballast.

During the past two years the Pennsylvania R.R. has been conducting an extensive and valuable series of tests in regard to railway ballast, the purpose of the tests being particularly to determine the depth which it is necessary to give for stone ballast on main-line tracks in order to secure a proper distribution of train load upon the roadbed. The committee appointed to conduct the investigation was composed as follows: L. R. Zollinger (Engineer of Maintenance of Way), E. D. Nelson (Engineer of Tests), A. B. Cuthbert (Principal Assistant Engineer, East Pennsylvania Division), and G. W. Snyder (Principal Assistant Engineer, West Pennsylvania Division). A report was made in March, 1911, and by courtesy of the railway company and the committee this report was presented to the American Railway Engineering Association, through Mr. W. C. Cushing, President of the Association (and Chief Engineer of Maintenance of Way, Pennsylvania Lines West of Pittsburg). It has now been published in Bulletin No. 136 (June, 1911), together with a large number of photographs and diagrams illustrating the result of the tests. We give herewith an abstract of the report, which is of particular value in view of the increasing loads and traffic which main tracks have to carry. The committee recommends the use of a ballast bed 24 ins. thick, and Mr. Cushing points out that this agrees very closely with the depth of 22.6 ins. given by the formula which Mr. Thos. H. Johnson derived from the experiments made in Germany by Mr. Schubert.

Description of the Tests.

At South Altoona a piece of single track was constructed, under which were placed three strong boxes open at the top and having removable ends, each box sufficiently large to contain two standard ties spaced the standard distance apart. The boxes were filled with various kinds of ballast and roadbed material. A heavily loaded truck was run back and forth over the track so that the effect of its load acting through the ties upon the ballast and roadbed could be studied by the removal of the ends of the boxes, when measurements and photographs could be taken. The track was 109 ft. in length, built of new 85-lb. rails, spiked to white oak ties 7 x 9 ins., 8½ ft. long; no tieplates were used. The rail fastenings were standard spikes, and the rail joints were so arranged as not to fall within the limits of the boxes. The 85-lb. rails were used in order that the track might be sufficiently flexible to subject the ties to as much weight as possible. The ends of the track were elevated to facilitate the stopping and starting of the car, but the part over the boxes was level. The ties adjacent to and between the boxes were kept slightly loose, as far as tamping was concerned, in order that the full weight of the car would come upon the two ties in each of the three boxes.

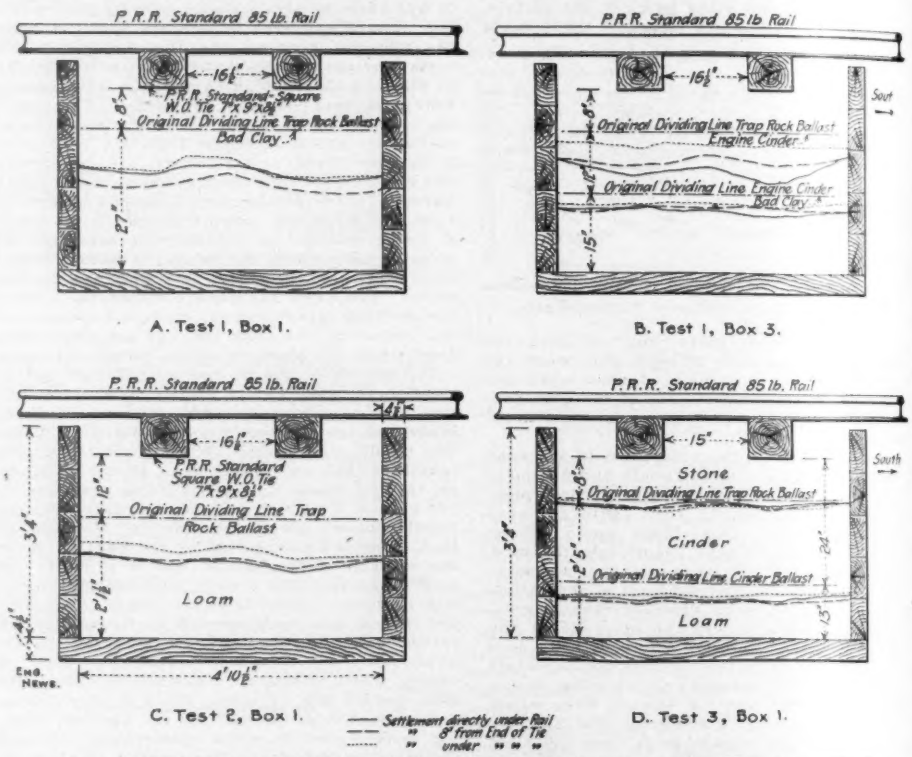


FIG. 1. SECTIONS THROUGH BALLAST BOXES, SHOWING CHARACTER OF SETTLEMENT DUE TO LOADS IMPOSED UPON THE TRACK.

The boxes were 12 ft. apart c. to c. They were 4 ft. 8½ ins. wide, 9 ft. long and 3 ft. 4 ins. high, being set so that their tops were 2 ins. below the base of the rail. The testing plant was roofed over to exclude rain so that the amount of water applied to the boxes could be accurately determined. In order to simulate natural conditions as to rainfall, water in known quantities was sprinkled over each box for the purpose of wetting the ballast and roadbed materials, to induce settlement, and possibly to produce pumping track (but the latter never developed). A careful record was kept showing when the water was applied and the amount in its equivalent in inches of rainfall.

The car or truck (having two axles) was run back and forth upon the track at a speed of about 5 m. p. h. It had a wheel base of 9 ft. and was loaded with pig iron, so that the gross weight amounted to 150,000 lbs., or 75,000 lbs. per axle. There was no spring intervention between the weight and the axle, the journal boxes being fastened directly to the body of the car. An electric motor was geared to one axle, the current being supplied through an overhead shoe bearing against a conductor. At the elevated ends of the track a device automatically shut off the current and reversed the motor; the car needed very little power or attention to keep it in motion. A counter on the car registered

the number of trips. The car was kept running night and day.

It being impracticable to run the car faster than about 5 m. p. h., at which speed any effect upon the track, due to impact alone, would be negligible, a weight of 75,000 lbs. per axle was chosen so as to obtain about the same effect on the track as an "H8b" locomotive [2-8-0] running at the usual speed. The weight per axle for this class of locomotive is 58,100 lbs. It was assumed that the effect on the track of the experimental truck was about as great as that of such a locomotive running at the usual rate of speed. Even if the assumption is open to question, the results obtained with the use of different combinations of material supporting the tie can be considered comparative.

The running back and forth of the loaded truck over the track resulted in a settlement of the ballast and roadbed materials contained in the boxes. After a settlement was noticed, aggregating about an inch, the car was stopped and the track raised to its original elevation and surfaced by tamping the stone ballast with tamping picks according to the usual service methods, the proper elevation and levels of the track being determined by the use of a "Y" level. The truck was then started and the above operation repeated from time to time, additional ballast being added, when necessary, to supply the loss due to tamping and settlement. In filling the boxes in each test, the loam, clay, engine cinder or other material, except the stone ballast, was compacted by a rammer.

The truck was kept running and the accumulated results of settlement were noted until the decrease in the daily settlement was so marked that it was considered time to close the test. Then the boxes were opened and at each end three vertical sections parallel with the rail were cut in the ballast and roadbed materials; the first was taken at the end of the tie; the second half-way between the tie and the end of the rail; and the third beneath the rail. Each section was photographed, also carefully measured by the use of the "Y" level, to show the curve or line between the ballast and the various materials with which each box was filled. In addition, measurements were made for cross-sections at right angles to the track; under the middle of each tie and midway between the ties. [See examples in Figs. 1 and 2].

A series of five tests has been completed; the first one beginning Sept. 2, 1908, and the last one ending Aug. 2, 1910. The diagram, Fig. 3, shows the relative position of the various kinds of material used in each box and for each of the five tests.

Summary of the Tests and Results.

TEST NO. 1.—The ballast conditions were as follows: each box had 8 ins. of standard broken trap-rock ballast, with 27 ins. of bad yellow clay in box No. 1, 27 ins. of good sandy loam in No. 2, and 12 ins. of engine cinders on 15 ins. of bad yellow clay in No. 3. During the test (81,600 round trips of the car) water was sprinkled over the boxes to an equivalent of 98¼ ins. of rainfall; an endeavor was made to produce the condition of "pumping" track, but without success, as the water escaped rapidly through the boxes.

An inspection of the boxes showed that in every case the depth of the ballast beneath the bottom of the tie had been materially decreased, due to the compression of the roadbed material and the sinking of the ballast into the material beneath it. The line of demarkation between the bottom of the ballast and the roadbed material was not straight, the ballast having formed a saucer-like depression in the roadbed material beneath each tie under each rail.

In box No. 3 the original 12 ins. of engine cinder, between the ballast and the clay, was very considerably compressed, the bottom of the ballast immediately under the rail being forced about half way through the cinder. On the other hand, the clay showed very little compression, and the line of demarkation between the cinder and the clay was quite straight, while the line between the bottom of the ballast and the top of the cinder was very much depressed under each tie.

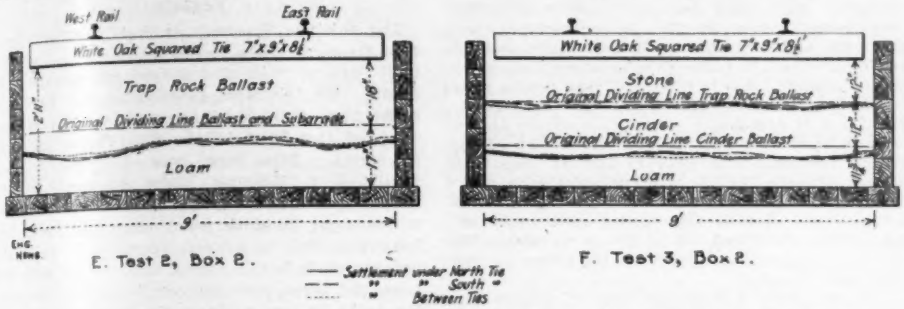


FIG. 2. TRANSVERSE SECTIONS THROUGH BALLAST BOXES, SHOWING CHARACTER OF SETTLEMENT OF BALLAST.

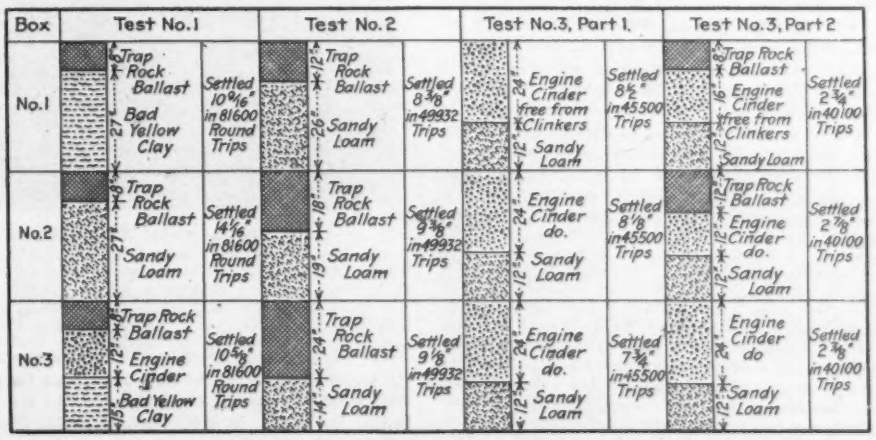
The test showed conclusively that a depth of 8 ins. of standard trap rock ballast, when laid on the usual roadbed material, was not sufficient to distribute the weight carried by the ties uniformly over the roadbed. The results in the third box showed, however, that if 12 ins. of permeable material, such as soft-coal engine cinder, is used beneath the 8 ins. of ballast, the distribution of the weight over the roadbed material was much better.

TEST NO. 2.—In this test, each box contained rock ballast on a bed of loam, but the thickness of the ballast was 12, 18 and 24 ins., with 26, 19 and 14 ins. of loam respectively. During the 49,932 round trips of the car, the sprinkling was equivalent to 11¾ ins. of rainfall. The inspection of the boxes showed that with 12 ins. of ballast, the ballast had been compressed a considerable distance into the loam, and that the line between the materials was far from straight, there being a considerable depression under each tie, especially under the rail. With 18 ins. of ballast, the ballast settlement was less and the dividing line was straighter, while with 24 ins. of ballast the settlement was still less and the line between the ballast and loam was quite straight. Sections made at right angles to the rails confirmed the conclusions that the deeper the ballast the straighter was the line between it and the loam.

After a careful consideration of the data presented by the second test, the conclusion seems inevitable that with standard stone ballast nothing less than 24 ins. beneath the tie will distribute the weight of the load uniformly over the sub-grade or roadbed. On the other hand, test No. 1 had shown that a depth of 8 ins. of stone and 12 ins. of cinder gave apparently fair results in distributing the weight upon the sub-grade.

TEST NO. 3.—Acting upon the above conclusion, this test was desired to show the advantage of a bed of cinders as sub-ballast, placed between the stone ballast and the roadbed. Each box was first filled with 12 ins. of loam covered with 24 ins. of cinders; the track was then laid in place and about 45,500 round trips of the car were made in order to compact the bed of cinders. Then 8 ins. of cinders were removed from box No. 1 and replaced with 8 ins. of stone ballast; in box No. 2, 12 ins. of cinders were replaced with 12 ins. of stone; box No. 3 remained unchanged. Then 40,100 round trips were made, or a total of 85,600 trips for the entire test. Water was sprinkled at the rate of ½-in. per day, or 15¾ ins. in all.

In the previous tests it had been noted that the water found its way through the stone ballast to the top of the clay or loam beneath it and there collected and ran through the cracks between the planks. In the third test, a new feature was introduced in box No. 3 by placing on top of the loam, beneath the 24 ins. of cinders, two pieces of iron pipe perforated with many holes. Each piece of pipe sloped from the cen-



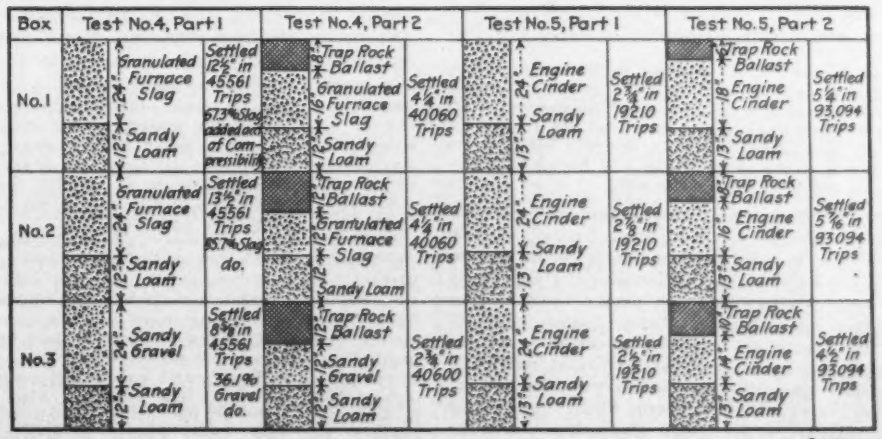


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FIG. 3. DIAGRAM SHOWING RESULTS OF BALLAST TESTS; PENNSYLVANIA R. R.

ter of the box outward to the end, a slot being made opposite the end of the pipe, so that it could be watched.

When the test was started (June 28, 1909), water equivalent to ½-in. of rainfall was applied daily. This was in progress for nine days, until water equivalent to a total rainfall of 4¾ ins. had been sprinkled before any moisture appeared at the ends of the iron pipe, and then only a very small quantity of slime began to ooze out at the ends. At no time during the test did water run freely from the ends of these pipes. This was considered a very significant fact, inasmuch as it showed the ability of engine cinders to absorb and dissipate a large amount of water falling upon it before the water was able to reach the sub-grade in sufficient quantities to do much damage by saturating it. During the experiments the pipes were carefully watched and kept clean from the inside, so that any water reaching them could be observed.

A study of the line separating the engine cinder and the loam, showed that in box No. 3 (where cinder was continued through the entire test and no stone ballast substituted) the line between the cinder and the loam was the straightest or best, showing the least amount of cupping. The line between the cinder and the loam in boxes Nos. 1 and 2 left very little to choose between them, with a difference slightly in favor of box No. 2 (12 ins. of ballast). At the same time it should be clearly noted that the sections taken at right angles to the track show the ties bent more in box No. 3 than they did in either boxes No. 1 or No. 2, due to the fact that engine cinder is more compressible than broken trap rock.

A study of the lines of demarcation, between the trap rock ballast and engine cinder in boxes Nos. 1 and 2, develops that there was less deformation or cupping of the cinder beneath the ties where the depth of stone ballast had originally been 12 ins. (box No. 2) than where it had been 8 ins. in (box No. 1).

TEST NO. 4.—This was made to determine the respective merits of gravel and granulated slag for sub-ballast, in comparison with the engine cinders used in previous tests. The test was made in the same way as Test No. 3. Boxes Nos. 1 and 2 had 24 ins. of granulated slag on 12 ins. of sandy loam; No. 4 had 24 ins. of sandy gravel. The track was then placed and 45,561 round trips were made; then 8, 12 and 8 ins. of the sub-ballast were removed, and replaced with the same depth of rock ballast in the respective boxes. It was noted that the compressibility of the gravel was about equal to that of the cinders, while that of the granulated slag was much greater. With the ballast in place, 40,060 trips were made, or 85,621 trips in all. During this time the sprinkling was equivalent to 14 ins. of rainfall.

This test developed the superiority of gravel when used for sub-ballast, as compared with granulated slag, the latter being much more compressible and unstable. There was little difference, however, in the line dividing the slag and the loam, and the gravel and the loam. This would seem to indicate that neither material had much advantage over the other in distributing the pressure upon the loam. A further study of this line showed that in box No. 2 (with 12 ins. of rock ballast) the line between the slag and the loam was a trifle better than in No. 1, with only 8 ins.

An inspection of the line dividing the ballast and slag and the ballast and gravel showed that there was more cupping or deformation where the ballast was only 8 ins. deep than where it was 12 ins. deep. Further, the line between the ballast and the gravel, was still better than between the ballast and the slag.

TEST NO. 5.—The previous tests indicated that the greater the depth of stone ballast, at least to 24 ins., the less is the deformation in the line or plane between the ballast and the underlying material. This test was made to determine whether a combination of stone ballast and sub-ballast having an aggregate thickness of 24 ins. would give as good a distribution of weight or pressure upon the roadbed as the 24 ins. of stone; also, whether there would be undue deformation of the plane separating the stone and cinders. The test was started with 24 ins. of cinders on top of 13 ins. of loam, the ties being placed on the bed of cinders and 19,210 round trips made to compact the cinders. Then 6, 8 and 10 ins. of stone ballast were placed in the three boxes, and tamped as in the other tests. The test covered 112,304 round trips in all, with sprinkling equivalent to a rainfall of 18½ ins.

The fifth test showed that there was less total settlement in box No. 3, where the depth of the stone ballast was the greatest, 10 ins. beneath the ties. Also, that there was less deformation or cupping between the line of engine cinder and the loam, and between the line of ballast and the engine cinder. But the line between the engine cinder and the loam in box No. 3 was not as good as the line between the ballast and the loam in box No. 3 of test No. 2, where there were 24 ins. of rock ballast beneath the tie and on top of the loam. This indicates that 24 ins. of trap rock ballast beneath the tie will distribute the pressure upon the sub-grade more uniformly than a like depth of rock ballast and compressed engine cinder combined, up to the point where the layer of engine cinder has a thickness of not less than 14 ins.

It is our opinion that any layer of engine cinders, having a less depth than 14 ins., would be sufficient to produce the results desired by the use of engine cinders; namely, a layer of material beneath the stone ballast which will absorb, lead off and dissipate water falling upon the track before it can reach the roadbed proper in sufficient quantities to be injurious.

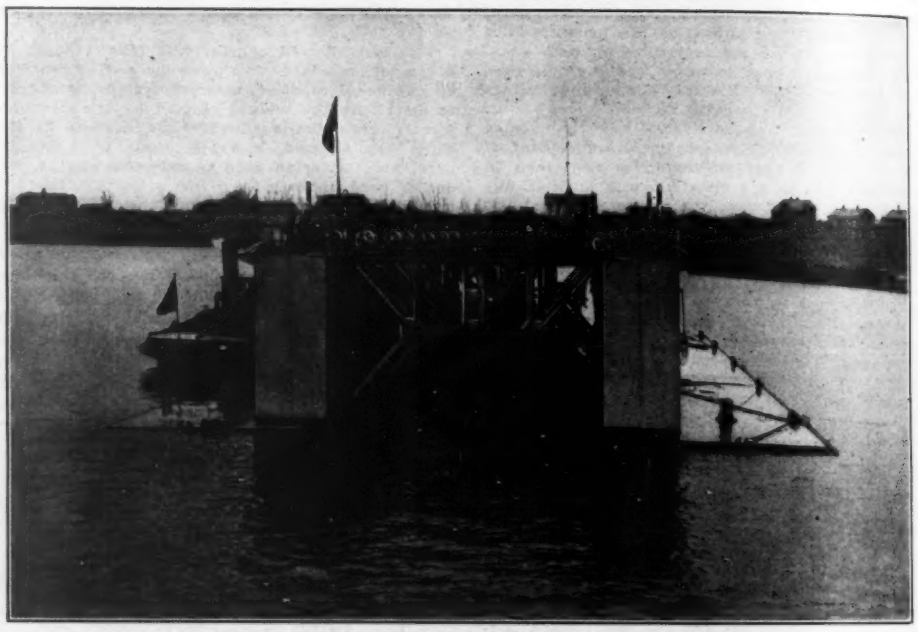
RECOMMENDATIONS.—On the basis of these tests, the committee recommended that for main line tracks on the Pennsylvania R. R. there should be 24 ins. of stone ballast under the ties, with a sub-ballast to prevent water from reaching the subgrade in such quantity as to soften it and reduce its load capacity. The recommendations are as follows:

A depth of 24 ins. of standard trap rock ballast, beneath which is an additional layer of 24 ins. of good permeable material, will place our sub-grade at a depth below the average frost line obtaining in the latitude in which the greater part of our system is located, thereby eliminating the trouble due to the action of the frost upon the roadbed and track.

Since the amount of wear and tear imposed on the experimental track and sub-soil during the various tests was very small compared with that to which our main line tracks are subjected under service conditions, your committee recommends the use of 24 ins. of stone ballast underneath the ties to meet satisfactorily the conditions that exist to-day and which will probably become more severe as time goes on. Also, that in addition to the 24 ins. of trap rock ballast beneath the ties, there should be provided a layer of engine cinder, gravel or an equivalent, to act as an absorbent mat to promptly and properly dispose of the water falling on the track in such a manner as to prevent its softening the roadbed material. Where the material forming the roadbed is of poor quality, the mat of engine cinder or gravel will also prove advantageous to prevent its working up into the ballast, thus shutting off drainage.

The Floating Dock for Raising Sunken Vessels.

The raising of vessels sunk in canals or narrow river channels is always a matter of difficulty, and may involve serious interference with traffic. The German government has had built a floating dock specially designed for salvage work of this kind in the Kiel Ship Canal and elsewhere. The dock was designed by Mr. Phillip Von Klitzing, Chief Engineer of the German Shipbuilding Co.'s plant at Kiel, at which plant the dock was built. The design has been patented in several countries. While the present dock has a lifting capacity of only 800 tons, the same principle can be applied to similar docks of larger size. The accompanying cut shows the dock afloat, with a barge slung between the two pontoons. The illustration and the following description are taken from the "Engineer" (London) of May 5.



A GERMAN FLOATING DOCK FOR RAISING SUNKEN VESSELS.

The dock consists of two L-shaped pontoons connected by open-work girders. Each of the pontoons is divided into water-tight compartments by longitudinal and transverse bulkheads. For sinking the dock, water is, of course, admitted into these compartments, and for lifting it centrifugal pumps driven by benzine motors are employed to empty the compartments. The length of the dock is 150 ft., and the distance between the pontoons is 27 ft. It is designed to lift vessels up to 800 tons in weight and 200 ft. in length.

When engaged in lifting a sunken vessel, the dock is securely anchored in position above it, and its lifting ropes are connected to the latter in any convenient way. There is an ingenious arrangement by which the tension on all the lifting ropes is equalized. By it the various load points are connected together by means of a compensating rope running in pulleys. Before the operation of lifting is begun, this rope is stretched tight by means of winches, and the load points are kept separate by means of rope stops. The dock is first of all sunk to its full extent, and the lifting ropes made taut. The pumps are then brought into play and the sunken vessel is gradually raised.

The extent of one lift is about 26 ft. 3 ins., and this can be performed in about three hours. The power of the pumps is about 30 HP. It is to be understood that the depth from which a vessel can be raised is not limited to 26 ft., for the lift can be repeated over and over again, the dock being sunk and pumped out, and the proper adjustment of the ropes being made each time. The only limit is the depth at which divers can work. The vessel as it is raised is brought up between the two pontoons, and when raised to the surface it can be repaired and pumped out.

Mitigation of Electrolysis of Pittsburg Water Pipes.

In a paper before The Engineers' Society of Western Pennsylvania, June 20, 1911, Messrs. E. E. Lanpher and L. B. Smith, of the Pittsburg Water Bureau, described the work done in that city since 1905 to reduce the destruction of water mains and service connections by railway return currents.

In 1900 investigations showed an alarming frequency of breaks. As practically all damage was in the vicinity of the power-houses of the Philadelphia Co., which operated all the electric railways of the vicinity, the trouble was attributed to stray currents returning to these power stations. Prior to 1900 no serious trouble, traceable to electrolysis, had developed though it was believed that the action had been slowly progressing. Up to 1905, the city and company were endeavoring to come to some understanding as to the responsibility for the conditions. The company at first contended that stray currents were not responsible, but later accepted this idea and claimed that it was a necessary evil as the company had bonded its track and had done all that could be expected. About 1905, two court decisions fixed the responsibility of the company. Mr. E. E. Brownell, of Chicago, was secured to make a survey and to formulate recommendations. The city and the company shared the expense and information. Mr. Brownell's report showed several centers of serious conditions: (1) An area of three miles long by a quarter mile wide centering at the 20th St. power-house of the Philadelphia Co.; (2) a narrow strip three miles long about the Glenwood power-house; (3) an area 1½ miles long by a quarter-mile wide about Bedford and Wylie avs.; (4) small districts about (a) Center and Millvale Aves.; (b) Penn and Highland Aves., near the Broad St. power-house; (c) four blocks of Ellsworth Ave. The map shows that the most troubled areas were along the Allegheny, Monongahela and Ohio Rivers. The maximum positive potentials were about 24 volts, in the 20th St. district, gradually becoming less in easterly and westerly directions. In the Glenwood district, 14 volts positive was found near the end of the pipe system near the Glenwood power station. A maximum of 5 volts positive was found in the Bedford district. (Positive potential was taken as voltage of pipe system above rails.) The greatest damage occurred in the 20th St. district, though there was extensive damage in the Glenwood and Bedford districts. The leaded joints showed little deterioration either of the lead or cast iron.

The report recommended (1) the copper bonding of every calked joint in the positive districts, and (2) the connection of the water mains at various points in the positive areas with the negative bus-bars of the proper power-house.

After much controversy the Philadelphia Co. was persuaded to go ahead on these lines, and in 1906 the company contracted with Mr. Brownell to install a "return pipe-feeder system" for the railway, using the city water and the company's gas main as returns for railway current. The city was represented on the work by the engineers of the Water Bureau for obtaining a record of the work, for assisting in the location of the pipes and for seeing that the service was not interfered with. The work in the 20th St. district alone is described in the paper noted, being typical.

The points of greatest positive potential (20th and 21st Sts.) were first attacked, eight 1,000,000-c. m. cables were run from the power-house to and along the pipes in danger, including a 42-in. steel conduit, a 36-in., two 12-in., a 10-in. and some smaller cast-iron calked-joint mains. These cables were connected by inserting a plug in the main much as in inserting corporation cocks, the plug end being faced and tapped out to receive the cable-terminal clamp. In some cases the cable connection was made by inserting a contact-plate terminal of the cables between the bolt heads and flanges—one bolt being loosened at a time. These cables were controlled by switches at the power-house.

It was found on trial that, with a station load of 12,000 amps., 4,600 amps. were returned from the pipes and the positive potential of the former danger center was reduced to 1.8 volts with corresponding reductions generally in the district, except near (1) Liberty Ave., (2) 32d St., and (3) west of 21st St. Pipes below 21st St. were positive to pipes above and current was forced into the section above 21st St. The drop on the cables along 21st St. to the power station was high—7.5 volts. Four more 1,000,000-c. m. cables were run into the section from the station, reducing the peak to practically 0.5-volt oscillating positive and negative.

A peak at 17th St. was next attacked, a 2,000,000-c. m. cable line being run from the 20th St. power-house to pipes on Liberty and Penn Aves., connecting at various points between 17th and 20th Sts. Satisfactory results were not secured, due mainly to the high resistance of pipes along Penn Ave., and the operation of a power station at 13th and Etna Sts., to reinforce the 20th St. power plant for about 5 hours a day. However, the current on one set of cables laid to the vicinity of 21st St., was reduced so that two of the cables were changed to relieve other sets overloaded, as noted. Two No. 0000 cables were run from 12th to 25th Sts. along the Penn Ave. pipes and connected to them at several points. A 1,000,000-c. m. cable was run from the pipes of Liberty and Penn avs., at 12th St. to the 13th St. power-house. The maximum positive potential had thus been reduced in this area to 0.5-volt, but it had required 5,000,000 c. m. of copper from the 20th St. power-house to pipes in Penn Ave., at 17th, 18th, 20th and 21st Sts., and in Liberty Ave., at 17th St., in addition to the 11,000,000 c. m. leading to the 21st St. area, the 1,000,000-c. m. leading to the 13th St. power-house, and the two 0000-cables on Penn ave. Where several cables, between the same points, were found carrying more current than others, they were equalized by jumper cross-connections.

When work was completed in this whole 20th St. district, the maximum elevation of pipe above rails was 0.5-volt under extreme railway loads. Some 86,000 lbs. of copper cable, aggregating 17,000,000 c. m. had been used. The greatest gain, however, it was believed, had been secured by utilizing the 42½-in. riveted-steel main as a return feeder.

Current from the Bedford-district pipes was returned through a cable suspended from the 17th St. incline-railway framework and thence along Liberty Ave. and 21st St. to the 20th St. power station. In the other districts the same results were obtained in much the same way. Where small and old pipes showed a high resistance, parallel copper cables were run. Many cases of poorly-bonded rails were found—especially at steam-road crossings, and these were bonded by copper cable.

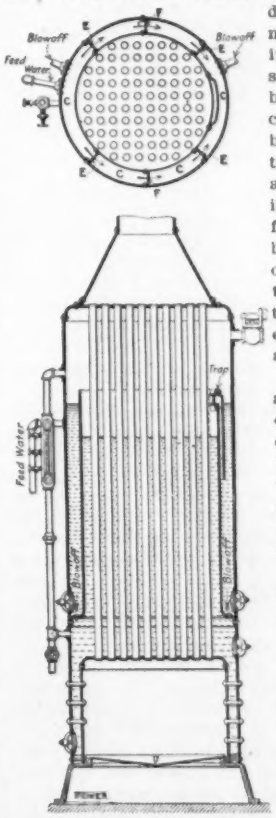
As the work was completed complaints were made that unbonded pipes of the People's Gas Co., and the cables of the telephone and telegraph companies were being increasingly damaged. Finally, the Philadelphia company agreed to bond these lines to the city water pipes.

A new 36-in. riveted-steel supply main was protected at Carson and South 30th Sts. by running five 1,000,000-c. m. cables to the negative bus-bar of the South 30th St. power plant. The main had been down but a year and was coated with mineral rubber, but showed pitting. Considerable work was done following the consolidation of Allegheny and Pittsburg, though on account of changing conditions it was made of rather temporary nature and calling for reinforcement later.

Under present conditions of increased station loads, the positive elevations of pipe potentials have advanced to above 1.0-volt at various points and further work needs to be undertaken. Surveys and examinations have been continued, but no line of water main has been found on which the electrolysis has continued since completion of the work described. The lead joints have not deteriorated from passage of return current along and in pipes nor is there evidence of damages due to shunting around defective caulked joints. The Water Bureau believes that if action is going on, the rate of deterioration is so small that the mains will fail, or become obsolete, from other causes first.

A Feed-Water Purifying Chamber for Vertical Boilers.

Most engineers are familiar with devices which have been brought out at various times for reducing the amount of mud and scale deposited on the heating surface of steam boilers, consisting of chambers inside the boiler, through which the feed-water passes and is raised to boiling temperature before it flows into the boiler proper. Blow-off cocks fitted to this chamber enable the sediment deposited to be discharged at intervals.



A Vertical Boiler with Interior Chamber for Purifying Feed Water.

A design for the attachment of such a chamber to the ordinary vertical tubular boiler has been worked out and patented by Mr. T. T. Parker, of Hackensack, N. J.

The accompanying cut reproduced from an article in "Power," of July 4, describing the device, will make clear the method of operation.

The chamber into which the feed-water is fed is formed by the space between the boiler shell and a cylinder riveted to its interior, leaving a space about 4 ins. wide. This annular space is divided by baffle plates marked E and F in the plan, the former coming within 7 ins. of the bottom of the tank so that the water flows under them, and the baffles marked F being in contact with the bottom but short enough so that the water can flow over their tops. The capacity of the annular chamber is about 100 gals., so that the water has a considerable time to deposit its impurities during its passage through it.

The addition of such a settling chamber to the interior of a vertical boiler should greatly increase the life of the crown sheet and the safety of the boiler and reduce the labor of cleaning.

Concrete Revetting in Culebra Cut.—Four tests are being made at Contractor's Hill, in Culebra Cut, on the Panama Canal, to determine the most economical and effective method of concrete revetment. The first method is to place rail against the side of the soft rock on 3-ft. centers, covering a space about 20 ft. broad, and then cover the rail with concrete. The second method is to place one inch square rods, 2 ft. 6 ins. long, in the soft rock on 3-ft. centers, and to anchor the revetment of concrete to the rock by these rods. The third, is to place the concrete against the rock in forms, but without puddling it to make a smooth surface, and then to finish the surface with the cement gun, this method to use neither reinforcement nor anchorages. The fourth method is to continue with the work of coating the soft rock by means of the cement gun.

The purpose is to determine the kind of protection to use in covering the decomposing rock below the 95-ft. level in Contractor's Hill, and at other points along the Canal. Chagres River gravel, which is mixed with sand in proper proportion, and one barrel of cement to the cubic yard of material, are used in making the concrete.—"Canal Record," July 26, 1911.

A Large Fan and Air Conditioning System for a Cotton Mill.

By L. L. LEWIS,*

The accompanying illustration shows one of the largest fans ever built. Standing 21 ft. 8 ins. above the floor level, it has a total height from top of housing to bottom of the discharge of 34 ft. 2 ins. The blast wheel is approximately 20 ft. 7 ins. in diameter by 11 ft. 2 ins. wide, and revolves at the rate of 70 r. p. m., supplying 20,000,000 cu. ft. of air per hour. The diameter of the shaft is 9 ins. in the bearings and is increased to 10 ins. between the bearings. It is driven by an engine capable of developing 125 HP. This fan is used to supply air for the humidifying, heating, cooling and ventilating system recently installed at the cotton mill of the Sharp Manufacturing Co. in New Bedford, Mass.

Before entering the fan, the air is drawn through a humidifier which is approximately 25 ft. 2 ins. wide and 19 ft. 2 ins. high. The air in passing through this humidifier comes in contact with a spray of water from 1,600 nozzles under pressure from a centrifugal pump. During the warmer months of the year, the air is cooled in passing through the humidifier, by evaporation of the water, down to the wet-bulb temperature of the entering air, and is saturated at that temperature. A sufficient amount of this air is delivered to each floor by the distributing system of ducts to absorb the heat generated by the machinery and the heat transmitted through the walls and windows on that floor and to bring the temperature down to the point necessary to give the desired humidity. It is possible to cool the air passing through the humidifier as much as 18° or 20° on some of the hot, dry days of the summer and the amount of air delivered is sufficient to hold the temperature on the various floors of the mill down to a point below the outside temperature. An automatic and independent control of humidity is obtained by regulating the amount of air delivered on each floor.

During the winter months the air in passing through the humidifier is heated to a constant temperature, and this temperature is controlled automatically. This is accomplished by placing a steam jet in the suction line of the centrifugal pump. A thermostat in the fan inlet regulates the valve on the steam-jet line so that the water is heated the proper amount to raise the air to the required temperature and absolute humidity. An economy is effected in this heating by taking only enough air from outdoors to supply ventilation for the operatives, the greater portion of the air being returned from the mill.

As it leaves the humidifier, the air passes through an eliminator which removes completely the mist or entrained moisture carried over from the water sprays. The eliminator is made up of corrugated sheets of galvanized iron strongly braced by galvanized iron angles and so arranged that the air has a tortuous passage through them The sheets are spaced approximately 1½ ins. apart and are placed in a vertical position so that all water which is collected on them drains back into the settling tank, and as there are no horizontal projections on the eliminators, all dirt and solid matter is carried to the tank by the water. There are four corrugations in each sheet and the angle of each corrugation is approximately 135°. By cutting down the distance between the eliminator plates, it is possible to increase the angle between the successive corrugations so that the air in passing through is not forced to make any abrupt turns. Thus the resistance is made very small, while the effectiveness of the eliminator is not impaired in the least. The last two corrugations in the eliminator have slightly projecting lips so that the drops of water which collect on their surface cannot be carried through by the air currents.

The air passes from the fan into a horizontal underground duct having a cross-section of approximately 308 sq. ft. and is conveyed to eight vertical risers having a total cross-section of approximately 350 sq. ft. The risers are placed outside the mill and are constructed with double-sash, double-glass windows placed so that the lower portion of the mill windows are not obstructed and will allow the entrance of light into the interior. A slight reduction in cross-section proportional to the air carried is made in each riser just above the point of delivery. Heating is accomplished by means of vent sections placed in each of the eight outlets on each floor. Thus each floor may be heated or cooled according to whether or not steam is allowed to enter the indirect radiators. This is a very important point in this installation for the reason that the distribution of mill machinery gives a very unequal distribution of power which necessitates cooling some parts of the mill even in extreme weather and heating other parts during the entire winter.

This system in doing the necessary heating and humidifying is furnishing approximately 25,000 cu. ft. of air per hour per operative, which is far above any requirements for ventilation. The air which is introduced is always clean, fresh and wholesome so that the operatives should never have any trouble with ill-health due to bad ventilation, and they are subjected to atmospheric condition such as would tend to keep them in first class condition for work.

A 20-Ft. Fan for Ventilating a Woolen Mill.

Another way in which the system works for an increased production is by cutting down the number of broken ends, and by keeping the fibers in the best condition as regards temperature and moisture. This not only means an increased production but also a better class of work. A person who has never been inside of a mill equipped with such a system experiences his first big surprise immediately upon entering one of the rooms conditioned. During the hot summer months he would expect to find these rooms hot, stuffy and ill-ventilated, but when he enters he finds the air is clean and wholesome, with practically no odor from the product being handled, and that in fact it is even more pleasant than out-of-doors.

The fan was built by the Buffalo Forge Co., 490 Broadway, Buffalo, N. Y., and the heating, cooling and humidifying system was designed and installed by the Carrier Air Conditioning Co., 39 Cortlandt St., New York City.

*Carrier Air Conditioning Co., 39 Cortlandt St., New York City.

Fifty Years as Town Clerk of Grimsby, England, is the record of Mr. W. Grange and he is still serving in the same capacity, although 90 years of age. A celebration in honor of the completion of his 50th year of service was recently held in that city.

The Destruction of Masonry by Embedded and Attached Metal.

The cracking of masonry structures due to the undue expansion or eccentric pressure of embedded or attached metal is a common experience. Such cracking does not as a rule endanger the structural safety of the masonry, for it generally is in some minor portion of the structure which is not called upon to resist much strain, but on the other hand it is very unsightly and is apt to occur in prominent places, such as guard rails, bridge railings, etc., where its appearance may be noted by every passerby. A recent issue of the "Annales des Travaux Publics de Belgique"* contains a voluminous article by Mr. G. Denil, an engineer in the Belgian roads and canals service, reporting the results of a most extensive study into these cracks, in the course of which many hundreds of structures were examined. The paper itself contains views of some 50 cases of cracking, carefully selected from a mass of others as showing specific types of failure. From those cases, which the author calls a "clinical study," certain conclusions for safe work have been drawn. Although the space at our disposal will not allow of a complete translation of the paper, we have prepared a short abstract which presents the salient features of Mr. Denil's study.

In nearly every case of masonry construction provision has to be made for the attachment in one form or another of some steel or other metallic structure for which the masonry forms a base, or which is needed to complement the main masonry itself. These connections vary little from the straight piece of metal, embedded by means of a mechanical or chemical bond, or both, into a cylindrical hole drilled into the masonry bed. The shape of the hole may be changed somewhat to prevent easy withdrawal of the metal or to provide more effective mechanical bond for an expansion end and the cementing material may be lead, sulphur or cement, but in general the type remains the same.

When first placed these fastenings do not appear to affect the integrity of the masonry, but very often at the base of the metal rod or pipe there appear in time the familiar radial cracks in the stone indicating that some expansive action has occurred, forcing the stone apart.

Three general types of failure of masonry due strictly to embedded iron are recognized by Mr. Denil; those induced by too hard preliminary drilling or subsequent driving, those caused by the expansion in freezing of water standing in the grooves or drill holes in which the iron is set and, in by far the greater number of instances, those caused by the rusting and consequent expanding of the embedded iron or steel. In addition to these the author notes several instances of masonry cracking under a too concentrated load of the superposed metal and from the force exerted by the expansive force of a metal structure butting against it.

FAILURES FROM WORKMANSHIP.—The drill holes in which iron is embedded are often made carelessly by workmen anxious to raise their working capacity and who, therefore, use too large drills and sledges or mallets. In certain kinds of stone this induces minute crevices invisible when the masonry is laid, but which increase rapidly with exposure to the weather and under stress. Especially when the anchored rod is near a face, as is very often the case, these cracks soon spread to this face and a slab of stone is spalled off.

FAILURES FROM ICE.—These failures are infrequent, but several photographs are given by Mr. Denil showing their occurrence. They may be expected only when the drill holes or the grooves into which the iron fits are not completely filled by the iron, in which case water may enter and, in freezing, expand with such force as to shear off the stone. In most places where water may enter it has room for expan-

*"La Destruction des Maconneries par le Fer Inclus," by M. G. Denil, Ingenieur Principal des Ponts et Chaussees. Annales des Travaux Publics de Belgique, Dec. 1910, No. 6., p. 921-1010.

sion, if it freezes, which accounts for the rarity of the failures due to this cause.

FAILURES BY RUST.—As noted before, most of these fastenings are made by wedging a bar of iron into a hole drilled into the stone and then filling the remaining voids with hot lead, sulphur or cement of some sort. It so happens that the filling material generally shrinks away from the iron leaving it open to the attacks of the atmosphere and rust begins to form on the embedded bar. This increases very slowly, but very surely, until in time the space which it occupied is too small and it forces the masonry apart and the characteristic cracks appear. When lead is used as the filling agent an electrolytic action is set up and the oxidation of the iron is carried on more rapidly than when some other filler, not electro-negative to the iron, is used, but in any case the adherence of the filler to the iron is rarely close enough to prevent a slow oxidation and consequent cracking.

The paper shows a great number of views of such failures, mainly in slender stone pilasters to the top of which some iron attachment is fixed, such a post, for instance, as is commonly used to carry a bridge railing. In all of these views cracks appear radiating out from the embedded iron, in some instances of such an extent as to cause spalling of the stone. After his examination of many such structures M. Denil comes to the conclusion that "most of the structures, in which iron is fastened to stone will finally be ruined and the cause of the ruin may be attributed to the spontaneous expansion of the fastenings, on account of the oxidation of the iron."

REMEDIES.—The author suggests a number of precautions which will reduce this trouble.

(1) The number of such fastenings may often be materially reduced without damaging the design, and the fewer the fastenings the fewer the failures.

(2) Iron wedges should be prohibited. Many failures are due to these wedges, which form a rigid, unyielding connection between the iron rod and the stone so that when the rust begins to form, its expanding force is transmitted directly. If only lead is used between the iron and the stone, the lead can take up some of the expansion.

(3) The embedded rods should be plain and round so as to permit of the even distribution of the filler.

(4) Galvanization of the iron rods, so as to prevent rusting, is good practice.

(5) Wherever possible bronze, which will not rust, should be placed next the stone, and the iron be set in this bronze socket, leaving room for expansion between the two.

(6) The greatest care should be taken in the execution of the work so as to ensure a perfect drilling of the hole and its complete filling by the filler.

(7) Sulphur and cement are better than lead for fillers as they do not cause electrolytic action. When lead is used it should be of the very best quality so that its complete penetration into all of the crevices of the hole will be assured.

A Suspension Bridge Over the Rhine at Cologne will probably be built in place of an old pontoon bridge. The old bridge has long been inadequate, and several competitions for designs have been held, the latest until last year in 1898. Last year the city authorities resolved to proceed. Five prizes of $1,750 were offered. A street bridge with two electric-railway tracks was called for, 40 ft. wide over the roadway, with two 10-ft. sidewalks. The conditions made high esthetic merit important. The bridge is only a quarter mile above one of the modern arch bridges which cross the Rhine at Cologne. The first and second prizes were awarded to the Gutehoffnungshütte of Oberhausen. Both designs are for suspension structures of three spans (350 ft., 700 ft., 350 ft.), with wire cables of either locked-coil or parallel-wire construction (the latter has not hitherto been used in Europe). The stiffening trusses are to be of nickel-steel. The difference between the two designs is mainly in the architectural development. P. Holzmann & Co., of Berlin, designed the substructure.

Determinations of Specific Gravity, Absorption and Permeability of Brick.

A series of tests made by Messrs. D. E. Douty and L. L. Beebe of the Bureau of Standards gives some novel information on brick and brick testing. The work was reported before the American Society for Testing Materials at its recent annual meeting (Engineering News, July 6 and 13, 1911). A brief summary of the tests made and some of their results is given here. Building brick only was tested.

SPECIFIC GRAVITY.—True specific gravity is usually determined from pulverized material, so as to eliminate the influence of pores and voids. With a view to establishing uniform conditions for such tests, the influence of fineness of crushing was studied. Samples of the same brick crushed to powders of different finenesses showed different specific gravities, the finer powders showing the higher specific gravities. Crushing below No. 60 sieve, however, produced only slight increase of specific gravity. The authors recommend, therefore, that for specific gravity tests a powder at least as fine as No. 60 sieve should be used.

Tests were also made to find how closely the true specific gravity may be determined on whole brick or entire pieces by boiling them to fill all pores and voids with water. It was found that boiling 4 hrs. enables the true specific gravity to be obtained with satisfactory accuracy (within 1 or 2%), except in the case of brick of very low absorption, for which the divergence is greater. The various bricks included in this test ranged from 2.50 to 2.65 in specific gravity.

POROSITY AND ABSORPTION.—By shellacking the outside of a brick and then finding the specific gravity of the piece as a whole, the relative porosity or percentage of pore space was determined by dividing by the true specific gravity and subtracting from 1. The mass specific gravities of the bricks in the test were found to run from 1.9 to 2.3, and the percentage of voids determined therefrom as 10.9% to 28.9%.

The relation of absorption determinations to this porosity percentage was examined. Absorption being ordinarily found in percent by weight, for the present purpose it was converted into volumetric percentage. It appeared that this volumetric absorption checked well with the porosity percentage except for the bricks with lowest absorption. Thus, an absorption test properly carried out gives a correct gage of degree of porosity.

ABSORPTION TESTS.—The influence of time of absorption and other conditions of the test upon the results was investigated by comparing different methods of absorption: Simple immersion (total and partial); boiling one to four hours; immersion for a long period followed by boiling; and immersion after vacuum treatment. The lowest absorption was obtained with the vacuum method (av. 17.7% by volume). The highest absorption was obtained by four hours' boiling after 90 days immersion (20.5%), although boiling without previous immersion gave almost the same result (20.2%). There was considerable difference between the results obtained from four hours' boiling and one-hour boiling (20.5 — 18.3%). Generally speaking, a half brick gave slightly lower absorption percentage than the whole brick.

The progress of absorption during long-continued immersion in water was found to be about as follows: Calling the full absorption 100%, the absorptions after different periods were: 30 minutes, 55%; five hours, 64%; 24 hours, 70%; seven days, 76%; 17 days, 80%; 90 days, 90%; boiling four hours after 110 days, 100%. This set of tests was made in parallel series with complete and partial immersion on whole and half bricks. Complete and partial immersion gave practically identical results after the first seven-day period. The half bricks at all periods gave slightly higher percentages of their full absorption than the whole bricks (though, as seen in the preceding tests, the total, or 100%, absorption of the half brick was lower than that of the whole brick). It is evident from these figures that the common 24-hr. absorption test gives results quite different from the true total absorption, and very likely also will give a comparison between two bricks different from the comparison which would be given by a full absorption test, as it is improbable that both bricks would reach just the same percentage of their full absorption in the 24 hrs.

PERMEABILITY.—A number of bricks were tested for permeability under water pressure applied to one of the flat faces. The apparatus used consisted of a casing surrounding the brick, slightly smaller at the top than at the bottom. The brick was set flatwise at about half the height of this casing, and the casing then lined with a cement-lime mortar, slightly overlapping the edges of the brick. Above and below the brick there was an inner casing to retain this backing and to reduce the chance of water passing around the brick through the backing. The outer casing being closed at the bottom by a strong plate, the space below the brick formed a closed chamber. Into this chamber water was admitted under a pressure of about 28.5 ins. per sq. in., and the volume of water passing into the upper chamber was measured. Results obtained with this test arrangement for nine different bricks were as follows:

COMPARISON OF PERMEABILITY AND POROSITY OF NINE BUILDING BRICKS.

Voids, %.	Absorption by volume, %	Permeability in c.c. per sq. cm. per min.
28.9	26.5	1.60
23.5	21.5	0.50
21.9	22.7	1.96
22.9	22.8	2.0
23.1	21.2	3.23
20.5	18.4	0.84
17.7	17.2	0.57
10.9	12.4	0.28
12.1	6.8	0.59

This tabulation shows a pretty thorough lack of parallelism between the absorption values and the permeability values. It was stated by the authors also that similar tests were made with sand-lime brick since the paper was written, and these also showed lack of agreement between porosity and permeability.

A Steam Snow-Plow for an Electric Railway in Switzerland, illustrated in "Schweizerische Bauzeitung" of July 29, has some features of novelty. The railway is the meter-gage Berninabahn, completed last year; its line has some 7% gradients and curves as sharp as 148 ft. radius. Snow-plows which acted by shoving the snow aside proved entirely inadequate for handling the heavy drifts, and it was decided to procure a rotary, as used in America, in Norway, and on the St. Gotthard railway. The power required was estimated at 500 to 600 HP. for the rotary and 300 to 400 HP. for propulsion of the machine. The conductor wire could not deliver such an amount of power, however, and chiefly for this reason a steam plow was ordered. The sharp curves of the railway demanded a self-propelling plow rather than one which would be pushed by locomotives, and the wheel arrangement had to be such as to give great flexibility. As built (by the Winterthur Locomotive Works) the machine is carried on two three-axle steam-trucks, each having two 12 × 14-in. cylinders, the head ends of the cylinders facing each other at the middle of the locomotive. The wheels are 30-in., and the wheel-base of each truck is 5.6 ft. A frame of steel channels rests on the trucks by center pins and lubricated side bearings, the boiler and the rotary with its engine resting on this frame. The 8½-ft. rotary has a shaft of 7.1-in. journal diameter, bevel-geared at its rear end to an engine shaft driven by two 12 × 14-in. cylinders set on top of the frame about at the center line between trucks. The gearing reduces the engine speed 1:1.9. The casing of the wheel is cylindrical at the rear, and flares outward to square shape at the front, about 9½ ft. wide. Lateral wings enable a total width of 11½ ft. to be cleared. The wheel can work in either direction of rotation; pivoted cutters at the front edge of each blade are set to the proper position by the snow pressure. Its normal speed is 160 r. p. m. The whole machine is enclosed above the frame by a wooden cab. A separate four-wheel tender is provided. Exclusive of tender the locomotive plow is 32 ft. long over all, and has a total wheel-base of 13.9 ft. Its loaded weight is 50 tons.

Improving the Inland Port of Nantes, France.

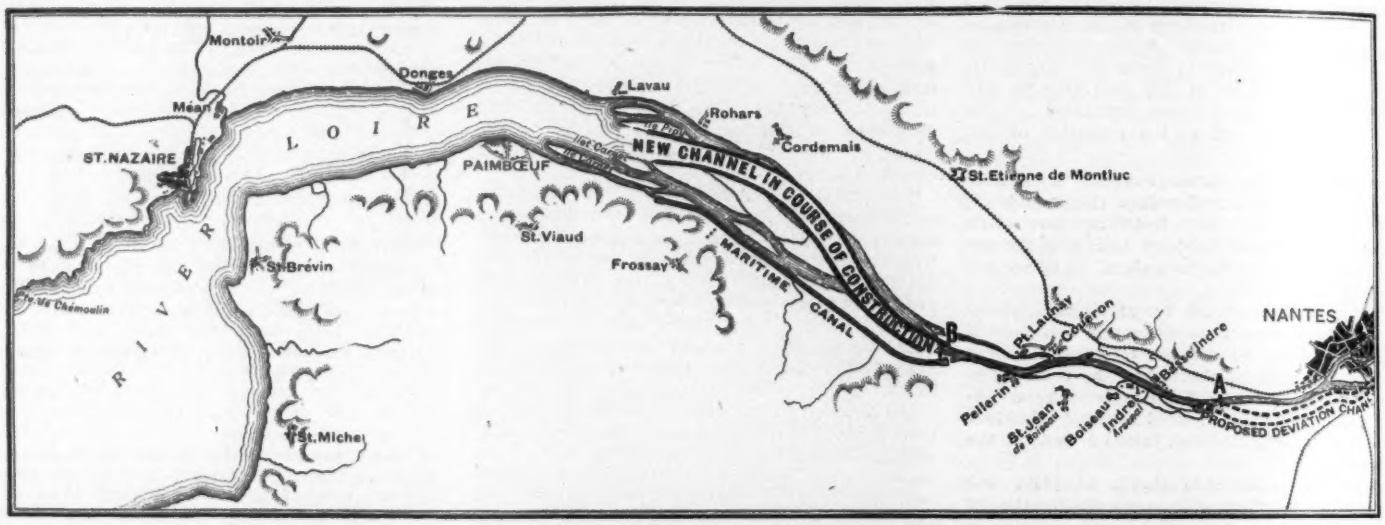
Inland seaports, located on the tidal portions of rivers, have to face certain disadvantages due to the increasing size of ocean steamers (and the consequent difficulty of creating and maintaining navigable channels of the necessary size) and to influences (such as floods or silt-bearing waters) which necessitate river regulation work of some kind. An interesting case of the fight of an inland port to retain its traffic, in the face of the above difficulties and of competition with a river-mouth port is afforded by the city of Nantes, France. The silting up of the river Loire had almost killed this city as a port, but it has largely regained its position by providing first a canal and then a deep-water channel in the river, while now it is proposed to go still farther and canalize a portion of the river by means of a dam and locks, and to provide a new river channel to the city. We give below a brief description of the new works and of the conditions which have led to their being undertaken, this being condensed from an article in "The Engineer," of London.

The town of Nantes is 35 miles from the sea, and is both a maritime and a river port. The river Loire is tidal to a point some 10 miles above it, and it is also served by the rivers Erdre and Sevre, which are both canalized. The estuary of the Loire is as utilizable for shipping purposes as is the Clyde, and it is hoped that, with the improvements which are now under way and which will be undertaken in the near future, it will develop into the point of departure of a navigable waterway, which would extend to Basle (Switzerland) and to which all the other waterways of France would link themselves.

The basin of the Loire has an area of 69,113 sq. miles, and contains about 12,000,000 inhabitants; very nearly one-third of the total population of the whole of France. The river has its origin in the deforested central portion of the country. During its course it passes over much friable rock, and consequently its waters bring down large quantities of sand. It is subject to sudden and devastating floods, though its average flow is small, for it has neither in filtration water nor that provided by glaciers, as have the Rhone and the Rhine. Until the forests were cut down and before the advent of the railways the river traffic was of considerable importance, and numerous lines of steamboats provided for the carriage of passengers. But in consequence of the deforestation the sand invaded the bed of the river, and little by little the channel became choked, navigation became more and more difficult, until when the railway came to compete with it, it very nearly disappeared. The towns on its bank shrank in size. The sand blocked the estuary as well, and eventually Nantes could only accommodate vessels of some 300 tons burden, and sank to twelfth rank among ports of France.

The necessities of the case caused the port of St. Nazaire [at the mouth of the river] to spring into prominence. The river was left to take care of itself. It was found, however, that traffic in anything which was not actually for local consumption at Nantes became impossible on account of the exorbitant charges for carriage and for the manifold handlings necessary, and the merchants realized that at all costs this state of affairs must be altered and means found to allow sea-going vessels to run up to the quays of their own city without unloading. After years of strife, they succeeded in carrying out improvement works in certain portions of the river, and constructed the "Canal Maritime de la Martiniere." This artificial channel (shown on the accompanying map) is 12 miles in length, and enables ships to escape that portion of the river which offers the greatest difficulties to navigation. Moreover, by it vessels drawing as much as 19 ft. of water can steam up to Nantes. From the very moment it was opened the trade of the inland port began to increase; the increase was due to the canal alone as the river traffic continued to be practically nothing. [The freight received and shipped increased steadily from 543,000 tons in 1893 to 1,533,700 tons in 1910.]

The Maritime Canal only permits of the passage of vessels of a maximum length of 394 ft., a maximum beam of 55 ft., and a maximum draught of 19 ft. Little by little it became too small as the vessels coming to Nantes became larger, and the activities of the port authorities were turned in the direction of improving the river itself. They certainly approached the work in no niggardly strain. It was decided to improve certain parts and completely to modify other portions with the idea of obtaining a navigation channel with a minimum depth of 26 ft. 3 ins.



MAP SHOWING THE IMPROVEMENT WORKS ON THE RIVER LOIRE, BETWEEN THE RIVER-MOUTH PORT OF ST. NAZAIRE AND THE INLAND PORT OF NANTES (FRANCE).

From a point marked B, just below the upper lock of the Maritime Canal, an entirely new river bed is being formed, which is to be contained between specially constructed banks. This type of river improvement is already in existence between Nantes and the Martiniere Canal. The width between the banks in the new works is to vary between 1,148 ft. up-stream to 2,624 ft. down-stream. The islands, sand banks, and shoals which lie between the lines of the two containing banks are to be removed by powerful dredges. The dredged matter is to be deposited on the landward sides of the river walls, so that land will be reclaimed and the walls themselves strengthened against the action of the water. More than 10,000,000 cubic meters of sand and alluvial deposit, will have to be dealt with in this manner, and it was estimated at the commencement that the work would occupy three years. When it is completed, the river will have an uninterrupted channel in which strong ebb and flow currents will be experienced, which, it is thought, will prevent the deposition of the sand and keep the passage free, so that when once dredged the channel will maintain its depth unassisted.

The cost of dredging is estimated at about $5,000,000. This work has been entrusted to the Tilbury Contracting & Dredging Co., of London, which has had a special dredge constructed for the purpose. This vessel has a total length of 174 ft., a maximum beam of 32 ft., a molded depth of 13 ft., and a displacement of 1,000 tons. It draws 8 ft. 3 ins. of water, and is fitted with two sets of triple-expansion engines, each of which either drives a propeller or the dredging apparatus. With 500 I. HP. the speed is 8 knots.

The vessel is fitted with a chain of buckets with an output of 800 cubic meters per hour, and also with a suction pipe and agitator which is worked in connection with a centrifugal pump. The material to be dredged is broken up by means of a disintegrator. The dredge can operate at a depth of 39 ft. 5 ins. The dredged material is either shot into barges, or else delivered behind the sea walls by means of a floating pipe, which can be extended to a total length of 3,296 ft. The diameter of this pipe, which is of the usual articulated type, is 2 ft.

Concurrently with the improvements in the river, some very important changes have been carried out in the port itself. All the older quays have been enlarged by the aid of concrete piles. These were driven further out in the river, and to such a depth that dredging to obtain a minimum depth of water of 23 ft. could be carried out. It would have been impossible to dredge right up to the walls of the old quays, as their foundations are not deep enough. A new reinforced concrete quay, 1,640 ft. long, has been constructed. Here the Orleans Ry. intends to receive the greater part of its coal. Next year 300,000 tons will probably pass through.

One thing alone threatens the port of Nantes; that is the danger of silt being brought up by the tide from the sea at times of low water in the river. The successful navigation of the Loire depends upon the lowest level of the water in the river itself. By reason of the dredging which is being carried on, the slope of the river bed is constantly increasing, and the flood tide flows with such force and speed that the corresponding ebb is also great, the tendency being to lower the river level more and more at times of low tide. This lowering of the river level is a very serious matter, as it means that the tide—or perhaps it would be more correct to say the sea—is getting the upper hand. The sand banks of the Loire are wonderfully stable; their movements are slow, and after each winter it used to be quite easy to put the channel again into the same condition in which it was before the floods. It is a comparatively easy matter to manage a river, but it is a very different question indeed to fight the sea and to protect the port from the matter the sea brings up with it. Ten months' dredging might well be ruined during the two remaining months of the year.

To obviate these inconveniences, to counteract the effects of the more decided ebb which the slope given to the channel produces, and to prevent the large vessels which can come up quite easily from finding themselves high and dry at low tide. It has been suggested to canalize the river for a length of 3 or 6 miles, according to different proposals, by means of a dam.

[One of the plans is for a dam and 725-ft. lock at A, on the accompanying map, with a new river channel to the city; above the city there would be a dam to control the floods and check the silt-bearing waters, and this would have locks for river vessels. The other plan is for a dam and 725-ft. lock at B; this would create a canalized condition all the way from the new ship canal to the city.—Ed.]

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A Notable Corrosion Study of the Longest Steel Water Conduit in the World.

No longer ago than 1903 there was put in use in Australia a steel pipe line 30 ins. in diameter and slightly over 350 miles long. Before the pipe line had been in use three years, considerable anxiety was caused by corrosion. Investigations were immediately set on foot, and as the trouble increased so did the study which was put upon the effort to learn why the pipe had corroded and what means could be taken to prevent its early destruction. We say early destruction because while the number of perforations of the pipe were small per mile they were particularly serious in view of (1) the great length of the pipe and (2) the fact that it was operated as a force main made up of many sections each with its own pumping station, so that a relatively few leaks in a year, considering the length of the pipe, might virtually keep it out of service a large part of the time. Moreover, not only was there external corrosion and leaks, but, what was perhaps more serious, there was internal corrosion and tuberculation, which was rapidly diminishing the carrying capacity, or increasing the pumping head, of the force main.

The studies relating to the corrosion of this main extended through five years, and were participated in by a considerable number of Australian engineers and analysts, and later by a commission of British engineers and analysts. Finally, the various problems involved, together with the various reports and the advice of the British commission, were referred to a Department Board for consideration and recommendation. This Board made its report early in 1910, and in July of that year steps were taken to carry out its recommendations. It should be noted, however, that from the beginning of the discovery of external corrosion work was prosecuted for stopping the external corrosion at the points in the pipe line where it was at its worst.

Inasmuch as the reports dealing with the corrosion of the Coolgardie conduit, as this pipe line is called, are not readily accessible in this country, we give considerable space to an abstract of them which appears elsewhere in this issue. The reports having been made over a considerable period by various men dealing with the subject from different viewpoints, no little time and pains have been taken in regrouping the information and opinions given in order to present in logical order the story of the corrosion and of the suggested means for overcoming it.

Having given so much space to our abstract of the reports, we will not duplicate the information there given by even a brief outline of the conclusions of the various investigators further than to call attention to a few salient points. The first of these which we shall mention is what appears to be a very unique proposition for preventing *internal* corrosion: treating the water with lime. The *external* corrosion is to be combated by exposing and recoating the pipe in those stretches where topography, soil and moisture conditions conspire to cause heavy corrosion, while, in addition, the conduit where exposed in the future will have placed under it a cradle of lime-concrete. This, it is interesting to know, is almost the only recommendation of the British experts adopted by the Australian authorities, so far as the prevention of corrosion is concerned.

The last remark leads us to say that the British experts were inclined to blame everything connected with the corrosion of the pipe, or unsatisfactory results with the supply in other particulars, upon the failure of the Australian authorities to carry out to the letter the recommendations of an earlier British commission which had been called upon for advice during the period of design and construction. The Departmental Board and several of its individual members in special reports all came strongly to the defense of these departures from the recommendations of the earlier Commission.

It may also be noted that the British experts based their recommendations for treating the water (by de-aeration) on the theory that the cause of internal corrosion was free oxygen in the water carried by the pipe. This they did, although they seemed to accept the present-day electrolytic theories of corrosion. The Australian engineers and analysts adopted hydrogen as the inciting cause of the internal corrosion.

Some of our readers will be particularly interested in the portions of our abstract dealing with the relative powers of cast-iron and steel to resist corrosion, and particularly in the testimony to the effect that mild steel is fully as resistent as cast-iron, while the resistance of the latter, as heretofore held by many, is often more apparent than real.

Finally, we call attention to a point which has nothing to do with the corrosion of the pipe line, but has considerable general interest. That is the great length, considerable diameter and enormous pumping head overcome in order to supply a few million gallons of water daily, nearly all of which is delivered at the extreme end of this 30-in., 350-mile pipe line.

Another Victim of Partisan Politics.

Every one who has followed the work of our state boards of health knows that within the last dozen years or so the Ohio Board has risen to deserved prominence. This has been largely due to the services of Dr. C. O. Probst, who has gained a national reputation in health-protective work, as has been evidenced by his secretaryship for many years and later his presidency of the American Public Health Association, as well as by the prominent part which he has taken in other national health and medical societies. Now, after twenty-five years of remarkably efficient service, Dr. Probst has felt that both his sense of duty to the state and due regard for his own honor have compelled him to resign his position.

Two years of opportunity to fill vacancies on the Ohio State Board of Health has given a governor with a different political faith than his predecessor control of that Board. The first notable result of this change which came to our attention was the dismissal, almost without a moment's warning, of a large part of the laboratory force of the Board, including its head, Mr. B. R. Rickards, who had but recently left his position as head of the laboratory of the Boston Board of Health to take up a similar position with the Ohio Board. Not thinking it wise or being unable to dispose of Dr. Probst in such summary fashion, the Board has hampered him in his work, according to his own public statement, and, in addition, has subjected him to the humiliation of appointment for a year only, whereas heretofore he has held his office as a permanent one. His appointment for a year, we understand, was made against the legal advice of the attorney-general of the state, who had reported that the only way to get rid of the Secretary was to bring charges against him. Dr. Probst's own statement is as follows:

> After mature consideration I have decided to resign as Secretary of the State Board of Health. I do this because under the present regime I am no longer permitted to direct the work along lines that seem to me of the most importance and for the best interests of the state.
>
> Furthermore, the recent action of the Board in re-electing me its Secretary for a term of one year, a thing that was never done before and is not contemplated under the law, makes the tenure of office so uncertain that no executive officer, even if unhampered, could count on carrying out broad and definite policies requiring time, which is absolutely essential in public health work.

If there is any branch of the public service which should be free from politics it is certainly the one responsible for protecting the health and very lives of the people. And it is likewise true that health-protective work, involving as it does plans looking far into the future, is in particular need of direction by a staff sure of continuance in office during good behavior and efficient service.

Arresting the Electrolytic Destruction of Water Pipes in Pittsburgh.

The measures employed in Pittsburgh to minimize the electrolytic destruction of underground structures, noted on another page of this issue, are of great interest, first, because of the discussions which have waged over the danger rather than the relief that would come from these particular methods (bonding the pipes to the negative bus-bars of the power-house), and, secondly, because of their bearing on the trend of judicial regard of interference of two public utilities. The cause for fear has rested chiefly in the prophesied inability to bond sufficiently well or on a large enough scale and in expected deterioration of calked joints. In the Pittsburgh case, however, these fears have not been realized in the few years since the work was completed and the progress of destruction seems to have been arrested. The chance of loopholes for leakage currents seem to be smaller, under the peculiar conditions there, than if insulating joints had been put into the pipe lines at numerous intervals. The bonding that was done appears to have been completed cheaper and quicker than insulating joints could have been slipped into place. Complete insulation of pipes was apparently as much out of the question, from the unwarranted expense and practical difficulty, as a two-conductor conduit or overhead system for the street railway.

The benefits that seem to have been secured in this case are not to be taken as an unqualified recommendation of the broad use of pipe-to-track bonding schemes. A warning still needs to be given against such promiscuous bonding; the work should be done as dictated by the results of careful electrical studies, before and during the work, by a competent electrical engineer.

There seems to have been some murmuring in the Pittsburgh case because the street railway has profited from the pipe bonding through improving the return circuit for its traction current by the addition of the pipe-lines as conductors. This seems a little like the old unjustifiable condemnation of any sort of cooperation with a public-utility corporation, even when the result would be an improvement of service. The water department permits the use of its pipe lines as an electrical conductor and receives in return protection against electrolytic destruction. The rail-

way company assumes the burden of the protective work of bonding the pipes and the responsibility of maintaining protection by keeping the bonding system to correspond with growth of the railway lines and service. This seems to meet present ideas as to the reasonable cooperation demanded in such cases by the decision of Judge Sanborn, in the Peoria electrolysis suit, which we printed at length in our issue of Nov. 17, 1910.

Defendant should be enjoined from continuing the injury to complainant's water mains and service pipes and should be given a reasonable time to take such measures or put in such improvements in its negative return as will substantially prevent injury. This should be on condition that complainant cooperate with the defendant so far as reasonable and proper in aiding it to prevent or lessen the escape of current from its rails, or in preventing the escape of current from the water pipes in such manner as to cause injury thereto.

Whether or not the Pittsburgh authorities assumed more than a reasonable share of the burden is largely a local question.

Do Farmers Want to Employ Agricultural Engineers?

The interesting remarks on "The Paucity of Instruction in Agricultural Engineering in the Land-Grant Colleges," which we reprint elsewhere in this issue, seem to take it for granted that the farmers of the United States would employ engineers if only men fitted to do the work which the farmers have in hand were available. While it may very well be that large sums of money, made available during the past few decades under the Morrill Act, have been used for quite another sort of technical education than was intended by the far-seeing Vermont statesman, we think if the farmers had really wanted engineers, not only the land-grant colleges, but other colleges with courses in engineering would have done their part to supply the need. Furthermore, we are strongly of the opinion that in most parts of the country there are plenty of not over-busy engineers who are fully competent to do any engineering work which the farmers are willing to put in their hands.

We do not mean to dispute the assertion contained in the article that the Department of Agriculture is besieged with letters from farmers inquiring how they shall line irrigation ditches, construct reservoirs, install pumps, erect windmills and drain lands; but, if we are not greatly mistaken, most of these inquiries have as their fundamental object the securing of free advice and are not prompted because engineers are lacking to answer the questions asked—and give right answers, too.

Whether or not we are right in our opinion, it is undoubtedly true that the time has now arrived when serious attempts will be made to turn some of the innumerable recruits who go from our technical schools to join the ranks of the engineering profession every year away from the older and more over-crowded branches of engineering and into such lines as agricultural and what may be more broadly termed rural engineering. It goes without saying that some variation, at least in training, is needed to fit men for these lines. It also goes without saying, as we have already tried to emphasize, that something should be done to educate both the agricultural and the general public to the need for and value of the services of engineers in connection with agricultural work. When we speak of the value of such work, we mean not only the value as measured by results which may be achieved, but also as measured by worthy service for which ample payment should be made.

As many of our readers know to their sorrow, farmers as a class are loath to pay out good money for professional services, and no little educational work will have to be done before their willingness to do this increases to such an extent as to make any very heavy demand on the engineering schools to turn out agricultural engineers.

Perhaps the greatest promise of better recognition of the need and value of engineering work from the farmers lies in an increase in the amount of instruction in engineering subjects given to students in the agricultural schools. Some knowledge of engineering principles and practice, even though that knowledge were elementary, would lead the progressive young farmer to appreciate the value of the services of the professional engineer and to call upon him more frequently for assistance when he was confronted with problems out of the ordinary. The example of a good sprinkling of farmers who had thus benefited from instruction in agricultural schools would gradually be followed by men who had not had the benefit of such training until finally there would be a fair demand for the services of an engineer in prosperous and progressive agricultural sections of the country. However all this may be, we think every one will agree that as soon as any considerable demand for agricultural engineers arises engineers and schools alike will rise in meet it.

Engineers and Engineering at the Coming Conservation Congress.

Considerable disappointment was expressed last year by engineers who attended the National Conservation Congress because so little attention was paid to what they considered to be the engineering and other practical phases of conservation. We are informed that those in charge of the third Congress, which is to be held at Kansas City, on Sept. 25 to 27 of this year, are taking much pains to secure a full representation from members of the engineering profession in general and from the various engineering societies in particular. To this end, we understand that invitations are being sent to all the societies listed in our issue of Aug. 3, 1911, requesting that delegates be appointed to attend the Congress. If, therefore, the engineering profession and engineering subjects are not properly represented at the Congress and upon its program, it would seem to be the fault of engineers themselves—provided, of course, that the program for papers and discussions is so arranged as to give engineers and engineering an opportunity. We would suggest that those who are particularly interested in this subject, especially if they have specific suggestions in the way of topics for discussion, communicate at once with Mr. Thomas R. Shipp, Executive Secretary, National Conservation Congress, Washington, D. C., or Mr. J. B. Hoyt, Chairman, Executive Committee, Kansas City, Mo.

The Importance of Proper Ballasting as an Element of Track Construction.

In the investigation of track materials and construction, with a view to securing greater efficiency and economy of the track structure under conditions of modern heavy traffic, much more attention has been given to the rails and ties than to the ballast which forms the foundation of the track and is an integral part of it. Studies of the form of section and methods of manufacture of rails, and studies of the preservation of ties by chemical treatment and protective tie-plates, have occupied the careful attention of engineers for many years, with the result that very great improvements have been effected in all these directions. But only within comparatively recent years has it been realized or recognized in a practical manner that the ballast is a highly important factor in securing good track, and that great improvement in the economy and the riding quality of the track structure may be obtained by giving greater attention to this factor. This improvement increases in importance with the increase in loads and traffic.

As far as engineering considerations are concerned, the ballast has been regarded in a somewhat perfunctory manner, and as a factor of secondary importance, belonging to the field of the practical track man rather than to that of the engineer. In this respect we have been somewhat behind European railway engineers, who for many years have studied and written about this element of track construction, both in regard to its theoretical and practical aspects; and they have looked at it from the point of view of the engineer instead of that of the roadmaster or the section foreman.

We by no means desire to depreciate the value of the work of the roadmaster and foreman, but their work is to use the material given them and to use it in a prescribed manner, rather than to conduct investigations as to the most suitable material or the best methods for its use. The design of rails or the determination of the best preservative for wood ties, for instance, would never be considered as matters within the proper functions of the roadmaster. Nor do we wish to imply that the proper character and use of ballast have been overlooked entirely by engineers. But their investigations have been largely with regard to the ballast itself, as an independent unit, rather than with regard to its relation to the track as a whole. Thus, there have been extended reports and discussions as to the relative merits of stone, gravel and other materials; the best size of stone, the cross section of the ballast bed, and the thickness of this bed. As to these points, the recommendations made have been based upon opinion and general experience rather than upon a scientific analysis of the conditions. In fact, there has been a somewhat wide impression that the track needs a bed of some loose material, fairly hard and well draining, but that large expenditures in getting specially good material would not be warranted, and that mathematical or theoretical analysis of the ballast problem would be an unnecessary refinement.

We hasten to say here that there have been important exceptions to the foregoing general statement, and there is an evident tendency to a more correct appreciation of the situation. Some of the engineering studies of the subject are referred to later, and we believe that the recent investigations on the Pennsylvania Lines (which are dealt with in more detail elsewhere) appear to give the most useful and practical results under conditions of American railway practice as compared with any other investigations of this kind. This is due partly to the carrying out of a complete series of tests, each set supplementing the previous tests; and partly to the fact that the tests were carried out on the scale of actual track construction, and under conditions closely reproducing those of actual traffic.

The studies of foreign engineers in this direction have been directed in four lines: (1) theoretical analysis of the problem of ballasting, with due regard also to practical conditions and limitations; (2) tests with small-scale models, which give valuable information, even if the results are not always directly applicable to actual track; (3) tests on a large scale, with actual ties and ballast, and some means of applying intermittent loadings of varying intensities; (4) observations of the behavior of actual track (whether of special or ordinary construction) for periods of sufficient length to permit of the determination of definite conclusions. In this country, such studies as have been made are included mainly in the first class noted above, though a larger development in the fourth class may be expected.

The general purposes and functions of the ballast are set forth clearly in the following paragraph from Tratman's "Railway Track and Track Work" (1908).

The ballast is a most important item in securing good track, with economy in maintenance and operation. Its purposes are (1) to distribute the load over the roadbed, (2) to form a support for the ties, (3) to provide efficient drainage under and around the ties, and (4) to allow of surfacing and raising track without disturbing the roadbed. It should not be laid until the roadbed is finally completed to grade and should not be used for raising banks to grade. The quantity of ballast should be liberal, with a depth of at least 12 ins. under the ties for track with heavy traffic, and the depth should be kept as uniform as possible. Where an old roadbed has been frequently reballasted, the ballast will be found to extend to a considerable depth, gradually becoming poorer from being worked into the soil. This makes a good foundation for the ballast proper, but a bed of sub-ballast would be cheaper. As the ballast gradually works into the roadbed it necessarily settles from beneath the track, so that continual tamping and filling are required to maintain the

track in surface. The settlement being very uneven it is difficult to maintain a uniformly good ballast and support under the ties. Under these conditions it is well to provide for thoroughly consolidating the roadbed in the first place and then to cover it with a foundation course of sub-ballast. This may be a 6 to 8-in. bed of rough quarry stones laid on edge, as in telford paving; or it may be of broken brick, gravel, coarse slag or cinders. This foundation will assist drainage, keep the roadbed from becoming soft, and keep the ballast proper from sinking into the roadbed.

It has been urged at different times that economy in track maintenance might be secured by more careful construction and finishing of the roadbed, so as to obtain a dense mass and a hard well-shaped surface as a floor to carry the ballast. This would mean the construction of railway embankments in somewhat the same way as reservoir banks and drainage levees, where a dense mass with slight settlement and impervious surface is necessary. But such methods of construction, with the selection of material and the use of heavy rollers to compact the material and produce a hard surface for the roadbed proper, must be considered as quite out of the question under conditions of railway building. Allowance must be made, therefore, for some loss of ballast on new work, due to its being gradually worked into the surface of the roadbed.

This compression or depression of the roadbed and consequent settling of the track may continue for a considerable time. It will occur to some extent on the very best roadbed; its extent and duration will depend largely upon the material and character of the roadbed, the atmospheric conditions and the amount of traffic. In addition to this, there is a certain amount of crushing and settling and displacement of the ballast itself, due to loads, vibration, wind and rain, etc. For these reasons (among others) European railways have long used a sub-ballast bed for purposes of efficiency and economy: efficiency in increasing the permanent stability of the track, and economy in avoiding an excessive use of ballast proper. In this country, comparatively little has been done in this direction, but the investigations on the Pennsylvania Lines point to the desirability of the introduction of this feature in track construction, as a means of increasing the efficiency and permanence in an economical manner.

This bed of sub-ballast must not be confused with the bed of cinders very generally used to remedy conditions of soft spots in roadbed. In a paper on "Drainage of Soft Spots in Old Roadbed" (Proceedings of the American Railway Engineering Association, 1907), Mr. W. M. Dawley, of the Erie Ry., reviewed the causes of these soft spots and their deteriorating effects upon the track. He pointed out that the attempt at remedy is usually the arbitrary one of tamping and retamping the ballast, and finally laying ashes or additional ballast, or placing drains which do not really tap the soft spot. Examples of excessive movement of track and deformation of roadbed under such conditions are of very general experience. It should be said, however, that in recent years much more attention has been paid to the drainage of the roadbed by effective methods, in order to remove and prevent trouble due to soft spots. In this connection we may call attention to the suggestion by Mr. Schubert (mentioned further on) in regard to the use of a concave roadbed with longitudinal central drain. Such a roadbed, but with lateral drains only (and for embankments only, we believe) was proposed if not actually used on some part of the Eastern Ry. of France, several years ago.

We have referred at some length to roadbed conditions, since these are closely related to the ballast conditions and the track in general. We come now to the consideration of some special investigations as to these relations, the investigations relating mainly to the proper use of the ballast rather than to the character or quality of the material itself. This latter aspect of the ballast question has been dealt with in numerous papers and reports. We take up first some of the foreign investigations, and refer to them more particularly for the reason that these particular investigations (by Mr. Schubert and Mr. Braüning) have been translated into English and thus made more directly available for American engineers, few of whom would see or study information of this kind in foreign publications.

One of the serious troubles in regard to roadbed and track maintenance is the deformation of roadbed in clay formation. Under the effects of the traffic loads, the clay works up in ridges between the ties, displacing the ballast, so that in time each tie lies in a trough of clay. This condition has been investigated very carefully in Germany by Mr. Schubert, and the results of his work were given in the "Proceedings" of the American Railway Engineering Association for 1906. During the years 1887-1890, he made a series of experiments with models of reduced scale, and from these studies it was determined that such deformation would not occur if the depth of ballast beneath the ties was made 8 ins. greater than the clear space between them. But Mr. Schubert went further than this. In addition to suggesting an unusual depth of ballast, he made the rather radical suggestion that in clay cuts the roadbed should be concave; the center to be 3.28 ft. below base of rail and to have a tile drain. The use of a concave roadbed on cuts, in France, has been mentioned above. If the ordinary or convex surface is retained (in clay cuts), Mr. Schubert would lower the subgrade so as to give the ballast a depth of 3.28 ft. at the middle and 4 ft. at the sides (for double track). Concave roadbeds have been employed to some extent for highways in the southern part of this country, in districts liable to floods, according to a bulletin issued by the U. S. Office of Public Roads. With a width of 15 ft., the depression at the center is about 12 ins. The concave roadbed is filled with stone, broken brick, or sand; large stones or pieces are put at the middle to form a drain, but there are no laterals.

Following the publication of the results of the studies made by Mr. Schubert, objections were made to the use of a deep ballast bed on the ground that the conditions assumed (that is, in regard to the abnormal movement of the roadbed surface in clay formation) did not exist in practice, and that such quantities of ballast were excessive, involving unnecessary expense. But later investigations of existing railways showed exactly the conditions which Mr. Schubert had deduced from his experiments. Observations on one railway showed that in 1½ years after the construction of the line the depressions under the ties were 4 to 5 ins. deep, while a year later this depth had increased to 14 ins. Photographs of this track at three different periods showed first a wavy surface of roadbed, then a pronounced wavy surface (with the bottom of the depressions nearly flat), and finally a distinct trough form with almost vertical sides to the clay ridges between the ties. This track had only 8 ins. of ballast, but a generally similar effect was found on a line which had been given 20 to 24 ins. of ballast on account of the clay formation. In this latter case, however, the ridges were narrow and of triangular form, showing the effect of the heavier ballast bed in reducing their size.

It was found also, that while the railway regulations required 8 ins. of ballast as a minimum, this had been generally considered by the construction officers as a maximum, quite regardless of the character of the roadbed or subsoil. The result was an excessive cost of maintenance far outweighing any saving in cost of original excavation or ballast. Such a condition is by no means unknown in this country. Mr. Schubert recommended, therefore, that the standards should require for clay roadbed a ballast depth at least 8 ins. greater than the clear space between the ties, and that 6 ins. of sand or other porous material should be used for the bottom part of this ballast. This latter feature of sub-ballast we refer to again later on.

His investigations went into the question of the most suitable material for ballast; and experiments were made by filling boxes with different kinds of ballast and placing at the top a tie tamped in the usual way. The tie was then subjected to a load which was applied and released alternately by means of an eccentric, in order to represent the action of the wheels of a train. After a certain time the ends of the box were removed and the conditions of the ballast observed. The conclusions arrived at were that the best stone ballast was needed for a traffic of 2,000 or more axles per day; with a traffic of 1,000 to 2,000 axles, stone of medium quality would suffice, while with small traffic screened gravel or even common gravel would be sufficient. It was also concluded that as the depth of stone ballast increased, the distribution of pressure upon the roadbed became more uniform.

It is of interest to note that Mr. Schubert found at a large basalt quarry an accumulation of basalt screenings (¼-in. to 1¼-in. in size), this material not being considered suitable for railway ballast. Tests showed very good results, however, and he recommended its use. It would appear that this material (a product of the crusher) resembles the disintegrated granite (a natural product) which is used on some western lines in this country and which has proved to be a very satisfactory material. It is available, of course, only in certain districts.

The investigations by Mr. Schubert related entirely to stone ballast. But many railways are compelled to use gravel ballast, or find it suitable and economical under their conditions of traffic. The conditions with this material may be different from those occurring with stone ballast. With this idea in mind, an investigation was made by Mr. Braüning (in Germany) which included experiments with models as well as observations of actual conditions on certain stretches of track. Here again it was found that wherever clay or clay-bearing soil existed in the roadbed there was trouble, especially in regard to heaving by frost. The material of the ballast has no effect upon this condition, and in order to eliminate deformation of the roadbed under the action of frost it is necessary that the roadbed (to a depth below the frost line) should consist of a material which is constant under the action of frost. He stated that any bed of clean sand (even if composed of fine grains) would serve as a frost-proof subsoil. Among other matters which he investigated (by experiments with models) were (1) the flow of sand and gravel ballast under ties subjected to intermittent loading and to impact, and (2) the effect of moisture upon the carrying capacity of the ballast.

An abstract of a paper by Mr. Braüning, reviewing his experiments and observations, is given elsewhere in this issue. He recommended a total ballast depth of about 22 ins., with the ballast proper not more than 12 ins., so as to leave at least 10 ins. for a sub-ballast of clean quick-draining sand. The ballast should be filled as high as possible between the ties, as this increases the carrying capacity of the ballast which directly supports the ties. The width of the tie is of importance, but commercial conditions govern in this respect, so that theoretical conditions cannot be carried into practice. The spacing of the ties is of greater importance, and with a space decreasing from 3½ times the width to double the width of the tie, the carrying capacity of the roadbed increases rapidly. In this respect Mr. Braüning agrees very closely with the views of Mr. Byers, mentioned below. The limit is the minimum spacing which will permit of proper tamping, which is given as 14 ins. clear (24 ins. c. to c.) for ties 6½ ins. high. At joints, however, the spacing may be reduced to 10 ins. in the clear for ties 12 ins. wide.

There is no doubt that a careful and exact spacing of ties has an important influence upon the riding property of track and upon maintenance. In Europe, such spacing is very generally observed, the width increasing gradually from the joint. In this country, however, the spacing is generally arbitrary and often irregular (even on main track), although a closer spacing at the joints is common.

While investigations of this kind have been conducted to a less extent and during a shorter

period in this country than abroad, American engineers have made some valuable contributions to the subject, in the way of both theoretical and experimental investigation. Mr. Thomas H. Johnson (Consulting Engineer of the Pennsylvania Lines) made a study of the Schubert investigations (noted above) and from this derived a formula showing the thickness of ballast necessary to produce an equal distribution of the loads upon the surface of the roadbed. In 1906, this formula and the Schubert investigations were brought to the attention of the American Railway Engineering Association* by Mr. W. C. Cushing (Chief Engineer of Maintenance-of-Way of the Pennsylvania Lines), who stated that he had experienced the same trouble with the deformation of roadbed in clay cuts. A great deal of this trouble is due to insufficient ballast and insufficient protection or blanketing of the clay surface. The adverse conditions are aggravated in this country by the enormous axle loads, and, said Mr. Cushing: "It is time for the maintenance-of-way engineer to endeavor to keep pace with the requirements of economical transportation, which has called into existence the heavy axle loads." The idea suggested was not followed up by the Association's committee on ballast, its attention being given mainly to the consideration of the respective merits and proper use of different kinds of ballasting material.

Later on, Mr. O. E. Selby (Bridge Engineer of the C., C., C. & St. L. Ry.) submitted to the association a paper on "A Study of the Stresses Existing in Track Superstructure, and Rational Design Based Thereon."† He pointed out that when ties churn or track settles, it is not customary to investigate the reasons, to study the stresses to which the track is subjected, or to devise improved construction. The almost universal remedy is simply to re-tamp the ballast or apply some additional ballast to bring the track to its proper level. Analyzing the stresses and taking the Johnson formula (noted above) for depth of ballast, he arrived at a required depth of 18 ins. of stone ballast for track carrying heavy traffic, with axle loads of 50,000 to 60,000 lbs. This would be very costly, and it was suggested that economy would result from using a bed of gravel as sub-ballast. On the assumption that gravel has about half the cost and half the distributing value of stone, he proposed to use 12 ins. of stone and 12 ins. of gravel, making a total depth of 24 ins. instead of 18 ins.

The assumption was made that the maximum load on a tie is half the axle load, but there is uncertainty as to the distribution of the load by the tie upon the ballast, due to the irregularity in the density of the ballast obtained by tamping. Assuming, however, that the center is lightly tamped and that the bearing is uniform over a length equal to twice the overhang (or 20 ins. each side from the rail) the load (under the assumed conditions) would be 4½ tons per sq. ft., while with a lightly tamped center the load would 5½ tons, giving an average of about 5 tons. The unit stresses were found to be in many cases far in excess of what would be considered safe or good practice in a bridge structure; the result is seen in broken rails, cut and broken ties, loose and crushed ballast, and deformed roadbed. To quote Mr. Selby:

> There is no more justification for continuing a small than a large structure in service with unit stresses higher than allowable, except that a failure in the small one may not cause a disastrous wreck; consequently greater risk may be taken. This is the case with all the elements of the track except rail, hence we repair the failures as they occur and suffer a heavy maintenance expense in order to save the first cost of a better structure.

The subject was taken up in 1907 by the late J. W. Schaub, who pointed out that the distribution of load is effected by means of entirely independent supports (the ties), and placing upon the track department "the impossible task of so adjusting these supports that each shall bear an equal part of the load" (Engineering News, June 13, 1907). To effect a better distribution and to avoid the settlement, crushing and general disturbance or loosening of the ballast bed, Mr. Schaub proposed to lay the ties upon two lines of longitudinal I-beams embedded in the ballast and connected by tie-rods. These I-beams would not only assist in distributing the load from the ties to the ballast, but they would hold the ballast in place, and also give to the rail a uniform support, which it cannot have when adjacent ties have varying values as supports.

A thorough analytical study of the ballast and roadbed conditions was made by Mr. M. L. Byers (Missouri Pacific Ry.) in the paper on "Strengthening Track for High Speed Trains," which he prepared for the International Railway Congress (Engineering News, Feb. 3, 1910). He showed that under the average construction of track for high-speed lines in this country very little of the full supporting power of a yielding subgrade can be utilized. The result is seen in the deformation of the roadbed, its material swelling up in the spaces between the ties, in the manner described by Mr. Schubert (in Germany), whose tests have been mentioned above. We cannot here go into a review of Mr. Byers' work, and his paper is readily accessible for those who may wish to study it. We may mention, however, his conclusion that reduction in pressure on the roadbed or subgrade would be effected to much greater degree by reducing the tie spacing than by increasing the depth of the ballast bed.

The studies of Selby, Schaub and Byers were all of a theoretical character, applying engineering principles and mathematical methods to the subject. They are none the less valuable on that account, but it is particulary important to have them supplemented by experimental methods. We are glad, therefore, to be able to present in this issue a description of a very comprehensive series of tests made by a committee of engineers on the Pennsylvania Lines under conditions closely reproducing those of actual track and traffic. In a study of the results, the committee took into consideration the question of frost, which is considered by Braüning (whose tests also are noted elsewhere) as one of the important factors of the problem. For particulars of the experiments on the Pennsylvania Lines, we refer our readers to the article above mentioned, on another page.

In concluding our review of the several investigations of ballast in relation to géneral track conditions, two points may be referred to especially: the depth of ballast and the use of sub-ballast.

In regard to the thickness of the ballast bed, there is a rather striking coincidence of opinion among the investigators. Mr. Schubert concluded that this should be about 22½ ins. for stone ballast; Mr. Braüning's figure was 22 ins. for gravel, supplemented by the provision that the ballast proper should not exceed 12 ins., leaving 10 ins. for a bed of sub-ballast. The report on the Pennsylvania Lines experiments recommends 24 ins. of stone ballast upon a 14-in. layer of ashes or gravel. While this last goes beyond the German recommendations, it must be remembered that the loads here are very much heavier than in Germany; that the investigation considered a main line of maximum intensity of traffic. Also that Mr. Braüning's figure is for gravel ballast on roads whose traffic is not such as to necessitate the use of the more costly stone ballast. Mr. Johnson (applying the Schubert investigations to American conditions) arrived at a depth of 18 ins. of stone ballast; and Mr. Selby modified this by suggesting 12 ins. of stone on 12 ins. of gravel. Mr. Byers made no definite statement as to depth, but stated that greater uniformity in the distribution of the load upon the roadbed can be secured to better advantage by reducing the spacing of the ties than by increasing the depth of ballast. The practical experiments on the Pennsylvania Lines indicate that a somewhat greater depth is required than that arrived at by theoretical study.

It seems to us that one of the important indications of all the investigations is the opportunity for material improvement at comparatively small expense by the use of a bed of sub-ballast. This is of general application, whether the ballast proper is of stone or gravel, and whether the traffic is of ordinary or maximum intensity. The sub-ballast increases the depth between tie and roadbed, and so relieves the unit load upon the latter; it also protects the roadbed from water and supports and drains the ballast, preventing the latter from working into the roadbed. Thus, even if the depth of ballast proper is not increased, the track conditions should be improved materially by the introduction of the sub-ballast. This is entirely independent of the use of filling at soft spots in the roadbed, the sub-ballast being intended for general use as an integral and important feature of track construction.

*"Proceedings" American Railway Engineering Association (Chicago), 1906.

†Engineering News, Feb. 14, 1907. "Proceedings," American Railway Engineering Association (Chicago), 1907.

LETTERS TO THE EDITOR.

The Measuring of Elastic Limit.

Sir: The article in Engineering News of Aug. 10, 1911, on "The Cause of Occasional Low Elastic Limit in I-Beams; What is the Practical Meaning of Elastic Limit?" raises a very important question. There are in use two definitions for elastic limit (or as it is sometimes called the "true" elastic limit, to distinguish it from the "commercial" elastic limit or yield-point). One definition—The lowest stress which produces permanent set—is framed from the viewpoint of the engineer who wishes to know whether a given stress will injure the material of a structure or machine. The other definition—The lowest stress at which the proportionality of stress to deformation is found to be inexact—is framed from the viewpoint of the student of mechanics or the stress computer who wishes to know whether his fundamental assumptions hold for the problem under consideration. The two elastic limits are, in general, not quite the same for any material, and in either case the value for the elastic limit found in careful laboratory tests depends in no small degree on the sensitiveness of extensometer used, on the personal equation of the observers who handle the testing apparatus, and also on the personal equation of the draftsmen who draw the stress-deformation curves.

For some years the writer has felt that we have very little knowledge of the practical significance of the "true" elastic limit, and that under ordinary laboratory practice, using an extensometer reading to 0.0001-in. on a gage-length of 8 ins., the determination of the elastic limit for soft steel affords no more definite results than does the careful determination of the yield-point. In fact, in view of the very low values for elastic limit found by means of delicate mirror extensometers and by thermo-electric methods, it seems open to question whether with ordinary extensometers (sensitive to 0.0001-in.) the "true" elastic limit can be determined—if indeed it exists at all. It has become the writer's practice, in making reports of tests in which the elastic limit is required, to report two values: "Stress at first noticeable permanent set," and "Stress at limit of proportionality of stress to deformation," and to include with the report a statement of the sensitiveness of the extensometer used and of course a statement of the gage-length.

There are many structures and machines in successful use which by the presence of permanent set show that they have been stressed beyond their "true" elastic limit. The well-known tests of Prof. Stribeck on the stresses in ball bearings illustrate this fact in a striking manner. The behavior of a structure under a static load which stresses parts of the structure well beyond the elastic limit depends on the general stockiness or flimsiness of the structure, as well as on the amount of local stress. If the structure is well tied together, without any very thin parts under compression, it may carry without collapse loads which produce local stresses beyond the elastic limit or even beyond the yield-point of the material. If the structure is made up of thin, flimsy members the whole structure may collapse as soon as any part is stressed much beyond the elastic limit.

The question of the practical meaning of the elastic limit cannot be settled by laboratory tests alone. Careful study must be made of actual structures and machines, both satisfactory and unsatisfactory. This examination may in some cases be made much more useful by the careful use of the strain gage.

It is to be hoped that the efforts of Engineering News to call attention to our lack of knowi-

edge as to the significance of the elastic limit and to call forth discussion of that subject by engineers will be successful.

H. F. Moore.

Urbana-Champaign, Ill., Aug. 15, 1911.

The Highest Record for Engine Duty.

Sir: On p. 128 of your issue of July 27 there is a note entitled "An Engine Duty of 195,000,000 ft.-lbs." which contains some incorrect and misleading statements. The note states in effect that a guarantee of 195,000,000 ft.-lbs. per 1,000 lbs. of steam is guaranteed on some triple-expansion pumping engines for the city of Pittsburgh, said engines to run with a boiler pressure of 160 lbs. gage and 100° superheat. At the end of this article appears the following statement:

These guarantees even rise above what is claimed to be the record engine duty for any service—that of a Nordberg air compressor at Painesdale, Mich., which is reported to have shown by test the high figures of 194,930,000 ft.-lbs. per 1,000 lbs. of steam.

This last statement is not correct. The compressor referred to showed by test a duty of 194,930,000 ft.-lbs. per 1,000,000 heat units supplied to the engine. In other words, the heat consumed per horse-power per hour was 169.29 B. T. U. It ought to be very plain to any one with any rudimentary knowledge of heat and mechanics pertaining thereto, that 195,000,000 ft.-lbs. per 1,000 lbs. of steam is not anywhere near as good a performance as that shown by the Painesdale compressor, when to generate the steam it has to be evaporated from hotwell temperature to a pressure of 160 lbs. gage and, besides that, superheated 100°. The equivalent duty for 1,000,000 B. T. U. in that case would be somewhere near 165,000,000 ft.-lbs.

I may here state that the duty recorded on the Painesdale compressor was obtained with saturated steam; in fact the steam during the test was extremely wet. At the present date the duty on this machine is considerably higher than that shown by the test, for the reason that the boilers have been improved since the time the test was made, so that they now give a reasonably dry steam.

Hoping that this will correct the statements in the note above referred to, I remain,

Yours very truly,
Bruno Nordberg,
Vice-President and Chief Engineer,
Nordberg Mfg. Co.

Milwaukee, Wis., Aug. 8, 1911.

[Our quotation of the claimed record for the performance of the Painesdale compressor followed the rather definite statement put forward by a correspondent in our issue of March 10, 1910. Examination of the report on this compressor test shows that the record was 194,930,000 ft.-lbs. per 1,000,000 B. T. U., rather than "per 1,000 lbs. of steam," as quoted. We are glad to place the correct statement of that performance on record.—Ed.]

On the Use of Concrete and Vitrified Clay Pipe for Water Conduits.

Sir: I have read, with interest, the letter of Mr. Benjamin Brooks in your issue of Aug. 3, 1911, commenting on the selection of materials and designs for pipe lines, and advocating strongly the use of vitrified clay pipe in alkali soil.

Inasmuch as the reasons which he gives for arriving at his conclusions are based upon fallacious premises, I take the liberty of calling attention to a number of statements made by him which do not appear to be correct.

Kosmocrete pipe, as made at present in Brooklyn, is intended for sewer purposes and not for pressure pipe, and its porosity, about 6%, has never injured its use for sewers. Tests made by the U. S. Reclamation Service prove that concrete pipe, when subjected to internal pressures, may be made practically impervious, and for this reason the Government does not hesitate to use reinforced-concrete water conduits for heads up to 110 ft.* Kosmocrete pipe 12 ins. in diameter with 1-in. wall thickness, kept under increasing pressures, is able in a couple of weeks to withstand a pressure of 25 lbs. per sq. in. without any appreciable percolation. Kosmocrete pipe, 12 ins. in diam., bursts at a pressure of 45 lbs. per sq. in., showing a tensile strength of 270 lbs. per sq. in. for the concrete.

*Eng. News, Feb. 16, 1911, p. 208.

Mr. Brooks states that in a recent test, conducted in Kansas City, to show the comparative merits of vitrified clay pipe and various makes of concrete pipe, and at the same time to try out the new method of testing proposed by the Iowa Engineering Society, a 12-in. standard vitrified clay pipe appeared at a decided advantage when compared with a 12-in. kosmocrete pipe from Brooklyn. A conclusion, based on a single test, is not a safe one. Many tests made by the Bureau of Sewers of Brooklyn on 12-in. vitrified pipe of the highest grade and kosmocrete pipe, gave an average breaking load for vitrified pipe of 1,493 lbs. per lin. ft. and 2,014 lbs. per lin. ft. for kosmocrete pipe. These tests were knife-edge tests.

The method of tests proposed by the Iowa Engineering Society was rejected a number of years ago in Brooklyn for the reason that the results depend upon the manner in which the sand is packed about the test pipe. Judging from the criticism of Professor Marston's paper at the recent convention of the American Society for Testing Materials, it is hardly probable that his method for tests will become standard. I have made many comparative tests of ordinary commercial vitrified pipe and kosmocrete pipe, and in every case the kosmocrete pipe developed a greater strength. The vitrified pipe, used for the Brooklyn sewers at present, is of the highest grade, and must be to meet the stringent requirements. It is not at all probable that the pipe ordinarily sold throughout the country is of the same grade.

Mr. Brooks states that the order of preference for discharge capacity is vitrified clay pipe, wood stave pipe, concrete pipe and riveted steel pipe. I do not know from what tests Mr. Brooks arrives at this order. I would be inclined to put vitrified clay pipe towards the bottom of the list, if not at the bottom, on account of the fact that the warping in burning is so great that it is almost impossible to make concentric joints, the result of which is that for pressure pipes there will be an offset in the pipe every 2 or 3 ft., varying from ¼ to ¾-in., which will more than overcome the advantages due to its glazed interior. With concrete pipe a wonderfully smooth bore can be obtained. Careful and unbiased tests are necessary to determine a matter of this kind.

Gustave Kaufman.

26 Court St., Brooklyn, N. Y., Aug. 7, 1911.

The Low Rainfall at Lowell, Providence, New Bedford and Boston, 1832-40, Compared with Averages for 10-Year Periods Since That Time.

Sir: I have been a good deal interested in the abstract of Colonel Burr's report on "The Influence of Forests on Stream Flow in the Merrimac River Basin, New Hampshire and Massachusetts," which appeared in Engineering News for July 27, 1911. I think it states the conditions on our river very fairly. I notice also Mr. Freeman's letter in the same issue.

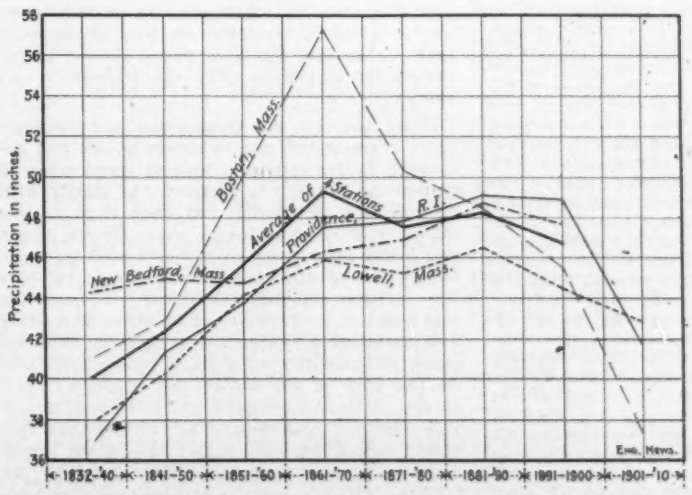
The following quotation and accompanying diagram (with figures and curves brought down to the close of 1910) are from a report made by me to the Reservoir Commission of Fall River in 1902:

* * * 19 years previous to 1850 the average precipitation at a number of places was as low as these two years (1899 and 1900). It is interesting to note that the average precipitation by 10-year periods rose steadily from 1832 to between 1880 and 1890; since which time the average has begun to decrease. While we should not attach too much significance to this, the fact remains that if we ever have ten continuous years with as low an average precipitation as fell during the years previous to 1840, a good many water-supplies in the state will have to be enlarged.

These differences in rainfall are shown in the accompanying table and diagram.

	Lowell.*	Providence.	New Bedford.†	Boston.	Average.
1832 to 1840..	37.98	36.87	44.27	41.02	40.03
1841 to 1850..	40.27	41.21	44.94	42.88	42.32
1851 to 1860..	44.14	43.73	44.76	50.09	45.68
1861 to 1870..	45.93	47.56	46.27	57.24	49.25
1871 to 1880..	45.24	47.84	46.88	50.26	47.55
1881 to 1890..	46.47	49.07	48.69	48.48	48.18
1891 to 1900..	44.46	48.89	47.72	45.46	46.63
1901 to 1910..	42.88	41.72	....	37.36	....

*Previous to 1861 Merrimack Mfg. Co.; after 1861 Locks and Canals.
†No records at New Bedford after 1906.



RAINFALL AT LOWELL, PROVIDENCE, NEW BEDFORD, AND BOSTON, 1832 TO 1910.
(The New Bedford record closed with 1906.)

There is a suggestion in this diagram that perhaps we have not reached the worst yet.

Arthur T. Safford.

Lowell, Mass., Aug. 4, 1911.

Kutter's Formula Coefficients for Rock Channels.

Sir: In your issue of July 27 I notice two letters, in regard to proper coefficient of roughness to be used in connection with Kutter's formula. I supposed that this matter had been threshed out to the extent that every engineer who pretended to measure water by the formula knew that it is a matter of judgment of the engineer who took the measurements, in regard to what coefficient to use for the particular conditions that confronted him. The coefficient as given in the text books represents the ideal conditions, but can not be relied upon when these conditions do not exist. The final court of adjudication is the judgment of the engineer who takes the observation. If he is a man who by years of experience has had opportunity to compare results of calculations by means of Kutter's formula with weir measurements and meter measurements his judgment may be good, but no definite coefficient can be fixed that can be used by an inexperienced engineer.

Example: A few years ago I was called upon to reconstruct a "barrel flume," built by Mr. Ham Hall for the Bear Valley Irrigation Co. and at the time of reconstruction owned by the Pacific Light & Power Co. The flume did not carry the amount that the company expected, owing to the deposit of a soapy-feeling substance that formed inside of the flume, which created sufficient friction to reduce the carrying capacity of the flume 25%. This matter was demonstrated by rebuilding 64 ft. of flume that had been destroyed by rock slide. The flume was rebuilt of exactly the same size, on same grade, and new "planed lumber" used. When the water struck this section the surface dropped 9 ins., and rose to same height as before when it entered the old section of flume. I showed this to Messrs. J. B. Lippincott, W. B. Clapp and Hall, of the U. S. Reclamation Service (at that time), and they said if they had not seen it they would not believe it.

Based upon several years of practical experience, I should advise that when an engineer figures that a conduit should carry certain amount of water on a certain grade according to ideal conditions of Kutter's formula, and expects that that conduit will carry the same quantity of water five or six years after its construction, he should add 25% to 30% to the cross-sectional area of his conduit.

E. Newman, M. Am. Soc. C. E.

Big Creek, Cal., Aug. 4, 1911.

The Newburyport Bridge and Other Early Suspension Bridges.

Sir: In connection with your very interesting description [Eng. News, Aug. 3, 1911] of the Merrimac River suspension bridge at Newburyport, Mass., the following notes pertaining to other early ones will be interesting.

History of bridge building in China has not been well preserved, and yet it is known that suspensions existed there nearly 2,000 years ago. Historians believe that China and India produced the first suspension bridges with iron chains. One of these in the Province of Yunnan is described by Kirchen, and is said to have been built by order of Emperor Ming, 65 A. D.; the length is given as 330 ft. Like all others in that country prior to the sixteenth century, it had the plank floor lying directly on the chains. Many others are reported in China, among them being one over the River Pei, with a span of several hundred feet. A remarkable one in Hindustan with a span of 600 ft. over the Sampoo River, is described by Major Ramel. In 1802, Humboldt found a suspension in Peru crossing the Chambo River, with the short span of only 40 ft., the cables of which were twisted roots, 3 ft. in diameter. He found another with a span of 131 ft., and cables 4 ins. in diameter supported on timber frames, the ends of the cables being fastened to posts driven into the ground. It was provided with side guards, but on account of its oscillation was very difficult to cross. Others in South America had cables made of cow hide. One of the earliest known suspension bridges in Europe was built by soldiers in 1515, to transport artillery over the Padus River in Italy.

The second suspension at Newburyport, which was completed in 1827, was at that time the longest one in America, and was exceeded by only two others, the Brighton Pier and that over the Menai Straits at Bangor. It contained five spans of about 200 ft. on timber towers, and in many respects was a more interesting and important structure than the earlier one finished in 1810. The towers of both bridges were quite similar, consisting of timber frames sheathed over and shingled. Descriptions of both the Newburyport bridges are given in the writer's "History of Bridge Engineering" and on page 212 will be found an illustration of the longer one, which was completed in 1827.

H. G. Tyrrell.

Evanston, Ill., Aug. 11, 1911.

Grade-Crossing Accidents.

Sir: The conclusion reached in your editorial regarding grade-crossing accidents, in the issue of Aug. 10, seems to be correct as to the only course that will eliminate the accidents, but is it reasonable to ask the people of this country to pay for this, the benefit of a small proportion of the population who are too careless to look out for their own welfare? I have followed with interest the accounts of various accidents to automobiles and their occupants at grade crossings, and should say that the "stalling" of the motor seems to be the cause of more accidents than any other one thing. This was the cause of the Raceville, N. Y., accident, and only a few days later a Bloomfield, N. J., doctor abandoned his car to destruction, while he and his wife reached safety by using the means of locomotion with which nature originally endowed them. The cause of stalling the motor is almost invariably an attempt to cross the tracks on the high-speed gear. Practically all railroad tracks cause a car to jounce, and hence the driver seeks to cross the track with his engine running at as low a speed as possible, but usually with the high-speed gear. If the driver would take the trouble to shift to a lower speed, the stalling of motors on railroad tracks would be far less common. This lack of thought on the part of the drivers is something that the whole community should not be penalized for. Just because the automobile owners of the country are wearing out the highways, built at a tremendous cost, there is no reason why, for their own convenience, the rest of the community should be saddled with another unnecessary expense.

R. T. C.

East Orange, N. J., Aug. 15.

A Shortage in the Water-Supply of a number of villages on the lower Hudson, not far from New York City, is reported. The villages include North Tarrytown, Dobbs Ferry, Ardsley, Hastings and Scarsdale, which are now supplied by the Consolidated Water Co.

The State Highway Construction in Massachusetts.

In view of the recent large appropriations for state highway construction in Pennsylvania, New York, California and other states, aggregating many millions of dollars, it is interesting to note from the recent report of the Massachusetts Highway Commission the progress, development and character of work done in the first state to establish a permanent highway commission. This commission was created by act of the legislature in 1893 and its first members were Messrs. Geo. H. Perkins, W. E. McClintock, M. Am. Soc. C. E., and the late N. S. Shaler, Dean of Lawrence Scientific School, Harvard University.

The total length of state highways constructed in Massachusetts to Nov. 30, 1910, was 837.6 miles. The total amount of money expended by the State Highway Commission for the construction of these roads, including the planting of trees, was $7,607,781. This makes the average cost of state road about $9,000 per mile.

Of the 54½ miles of road completed during the past year, 18 miles were of ordinary water-bound macadam, 6 miles of ordinary gravel, 6¼ miles of sand bound with oil, 2½ miles of bituminous macadam where the binder was incorporated in the top course, 6½ miles of ordinary macadam covered with a surface binder of asphaltic oil, and 14¾ miles of gravel with top course bound with a bituminous binder.

With the $500,000 annual appropriation for highways the Commission considers the greatest benefits are obtained by improving the main lines of travel between towns and cities, the large cities and towns benefiting most by having good connecting roads with the farming communities, over which produce is economically and quickly hauled. Consequently little is attempted in the immediate vicinity of large cities where traffic is so heavy as to require nothing short of an expensive pavement.

Particular attention is also being given to the improvement of the "small town" roads which may be termed secondary lines of travel. Since work of this character was started, about four years ago, 235 miles of such road have been improved, at a total cost of $401,503. In many instances the Commission has been able to improve long sections of road for a small outlay. On some roads the improvement consisted only in widening out the worst sections, shaping up the road, filling holes and ruts, blasting out a few ledges, and on such parts of the road as were in good condition doing practically no work. For these improvements the towns contribute a part of the expense, and agree to maintain the road in a suitable manner; failing to do so they must pay back to the state $50 per mile of improved road per annum, this sum being devoted to the expense of maintenance by the Highway Commission.

Under the law the Commission and its engineers are required to give expert advice and assistance to the various cities and towns when so requested. While it is impossible to comply with all requests very much has been done in this direction in securing better roads for the towns and better returns for money expended by them. It has also proved of great educational value to town officials who have charge of road construction and repair. It is one of the most interesting and promising developments in highway improvement, and not only adds much interest and zest on the part of the towns, but places at their service, without expense, a corps of exceptionally able highway engineers. The services thus furnished include not only expert advice, but supervision of work undertaken and paid for by the town individually, surveys and estimates, and designs for bridges and similar structures.

The maintenance of roads under automobile traffic continues to be the greatest problem. A good example of the rapid deterioration of a new macadam road is illustrated by a road built in the town of Becket in 1909. This road was built of the best local stone obtainable. It was not opened for traffic until late in the fall of 1909. By July, 1910, the surface of the road was so torn up and rutted by automobile traffic that an expenditure of over $1,400 a mile was required to repair it and apply a coat of asphaltic oil.

The application of some form of bituminous binder has proved the only practicable way of maintaining both new and old macadam, although the old macadam has much better resisting qualities than the new. For this purpose 1,300,000 gals. of oil were used in 1910. To purchase and apply this binder required the total amount of money available from motor vehicle fees, leaving all other maintenance charges to be paid for out of the general appropriation. The cost of treating a typical road with ½-gal. of oil per sq. yd. in two ¼-gal. applications, was 7.66 cts. This included cleaning, patching old surface, cost of oil, rolling, etc.

The experiments with sand and oil roads have proved very satisfactory. Asphaltic oil has been used in various ways in different places. The sand or gravel has been heated and mixed with oil, spread upon the road, and properly shaped and rolled; in other cases the oil has been heated and used in the so-called building up process, using an application of about ¾-gal. per sq. yd. on the shaped and hardened surface of the subgrade, and covering it with sand sufficient to absorb all the oil, then giving another coating of ¾-gal. per sq. yd. and another coating of sand, finally adding ½-gal. per sq. yd. to this and another layer of sand.

The latter method is cheaper than heating the sand and oil mixed, and where the subgrade was hard and well shaped and a uniform spreading of oil was secured it proved reasonably satisfactory. The road generally needed reshaping in some places, and where it failed it seemed usually to be due to the uneven distribution of the oil. When this happens holes develop and more oil has to be added, and the whole shaped, crowned and rolled into place. This can be done the second season, and, so far, has produced a reasonably satisfactory road at much less cost than required for macadam. By use of this form of construction the Commission hope to add many miles to the State road system, which would otherwise not be built because of the excessive cost of macadam.

A Boiler Explosion at Eaton, Ind., Aug. 14, in the plant of the Paragon Paper Co. damaged the mill to the extent of $1,000 and killed two men of the night shift. Reports state that two boilers exploded.

A Tornado in North Dakota caused the death of eight persons on Aug. 20. The storm appears to have been worst along the international boundary line. Many farm buildings on both sides of the line were destroyed.

A Mine Cave-In at Hibbing, Minn., on Aug. 19, buried several men under tons of earth and rock. The men were detailed to dig out a steam-shovel, which had been working on a wide shelf about 115 ft. from the top of the bank and 35 ft. above the bottom of the pit, and had been partially buried by a previous cave-in. The second slide buried the rescuers, but all except three succeeded in getting out alive.

Two Locomotives Were Wrecked on the Southern Ry., at Sueville, S. C., on Aug. 20, by falling through a burning trestle. The locomotives were drawing a passenger train, which, however, did not leave the rails. One fireman was killed, but no passengers were injured.

An Explosion of Gas wrecked the foundry building of the Illinois Steel Co. plant at Joliet, Ill., on Aug. 18. The explosion took place in a small furnace at one end of the building. Forty men were in the building at the time. The building was badly shattered, and the falling of the concrete roof slabs killed four of the workmen and seriously injured 13 others.

A Passenger Train Was Derailed on Aug. 13, just west of Columbus, Ohio, on the Cleveland, Cincinnati, Chicago & St. Louis R. R. The train was known as the Cincinnati and New York Special and was running east at about 40 miles per hour. According to reports the derailment occurred near the P. T. of a curve where the forward truck of the second coach struck a switch point

and was derailed. The first two coaches were thrown over an embankment, and two Pullmans were derailed and thrown across the tracks. Thirteen persons were seriously hurt, including the engineman and fireman.

A Fire Near Frankfort, Germany, on Aug. 19, destroyed the works of the Apel Sewing Machine & Bicycle Co., at Russelheim. Two persons were killed and the financial loss is said to be $1,000,000.

The French Steamer "Emir" sank Aug. 9 in the Strait of Gibraltar, five miles east of Tarifa, Spain, after a collision with the British steamer "Silverton." Seventy-one of the "Emir's" passengers and 24 of her crew were drowned, while 27 others were rescued by the crew of the "Silverton." The "Emir" was a vessel of 1,291 tons and was bound from Gibraltar for a Moroccan port. The collision occurred in a dense fog.

A Rock Fall in the Hales Gap Tunnel of the Virginian Ry., on Aug. 14, blocked traffic for several days. A freight train struck the fall, but was pulled out without damage. The tunnel is in slate and is timbered.

By the Fall of An Aeroplane Flyer, Lieut. T. J. Ridge, of the British Army, was killed at Aldershot on Aug. 18. The machine is reported to have been "a new-pattern military type."

H. N. Atwood, who has been attempting a cross-country flight from St. Louis to New York City, completed his ninth day by landing near Fort Plain, N. Y., 1,065 miles from the start and 200 miles from the finish. The first two days' runs were noted in our previous issue. The third day was spent between Elkhart, Ind., and Toledo, Ohio, 133 miles; actual flying time 2 hrs. 56 min. The fourth day ended at Cleveland, Ohio, 123 miles, the flying time being 2 hrs. 20 min. The fifth day saw the aviator at Swanville, Pa., near Erie, and 84 miles from Cleveland; the flying time was 2 hrs. 7 min. On the sixth day, 99 miles was covered to Buffalo, N. Y., the flying time being 2 hrs. 21 min. The seventh day saw 104 miles covered, to Lyons, N. Y., with 2 hrs. 11 min. of actual flight. On the eighth day Atwood covered 40 miles, officially, in 1 hr. 28 min., landing at Belle Isle. He reported having lost his bearings and made a detour. The 95-mile trip of the ninth day to Fort Plain was made in 2 hrs. 10 min. This makes the total time in the air for the 1,065 miles, 23 hrs. 32 min.

An altitude record for aeroplane flight, 11,726 ft., was reported made by O. A. Brindley on Aug. 18 at Chicago.

Boiler, Elevator and Flywheel Accidents in the United States and Canada during the month of May, 1911, as listed by the Fidelity and Casualty Co., of New York, killed a total of 30 persons. There were 22 boiler explosions in the month, but only five persons were killed by them. This is even less than in April, when eight persons (less than one-third the monthly average for the fall and winter) were killed. The number of elevator accidents, 94, is more than 50% larger than in April, and 25 persons were killed as compared with 13 in April. Only six of the 25 persons killed in May lost their lives by falling down shafts, an unusually small proportion. Three were killed by the falling of elevators and 16 were struck by elevators or caught and crushed. The worst of the four fly-wheel accidents in the month occurred in the electric light plant at Temple, Tex., damaging property to the extent of $2,000. No fatalities resulted from any of the fly-wheel accidents, and only three persons were injured.

The figures for June are nearly the same as for April, the total killed in each of these months being 23. Boiler explosions in June numbered eleven and killed seven persons. Elevator accidents numbered 67 and killed 13 persons of whom seven were caught and crushed and six fell down shafts. Fly-wheel accidents, of which there were seven, including grinding-wheel explosions, killed only three persons, but three others were reported fatally injured.

Three Lock Gates Were Carried Away at Lock No. 21 on the Welland Canal, near Thorold, Ont., on Sunday morning, Aug. 20, by the Steamer "Key West," upbound from Montreal to Ashtabula. The boat apparently was in a hurry to get through the locks before the Sunday tie-up that starts at 8 a. m., and not being held back in time, smashed into the upper gates, which were spread apart by the impact. The water rushing through tore out these gates and one of the lower gates and carried the boat well down the lower level, but did not injure it or any other vessel very seriously. The damage was repaired in remarkably short time by the canal force, navigation being resumed the same day in time for the regular Sunday night lock-opening hour, 9 p. m.

The Bridgeport Wreck on the New York, New Haven & Hartford R. R., which occurred on July 11, was reported upon by Chief Inspector of Safety Appliances, H. W. Belnap, of the Interstate Commerce Commission, on Aug. 17. The report states the controlled manual block signal system was in good working order, and that ample warning was given the engineer that the crossover was to be taken. The interlocking plant is not equipped with approach locking to prevent signalmen from changing the switches while a train is closely approaching them, but there is no evidence in this case to show that the absence of approach locking in any way contributed to this accident. The crossover frogs were No. 8. The report states that the accident might have been avoided by using No. 18 or 20 frogs, but that the location of the crossover near the P. T. of a curve made such a long crossover impractical. The report concludes that the signals and rules, had they been observed, were adequate to prevent such accidents; that the accident was due to disregard by the engineman of the rules and signal indications; that in all locations where accidents are likely through the non-observance of rules and signals, automatic train-control apparatus should be provided; that in the absence of such control, on tracks where high-speed trains are run, switches should not be set to divert trains from one track to another on a crossover not safe for high speeds, until the train has been brought to a stop; that all interlocking plants where high-speed trains are operated over facing switches should be provided with approach locking.

The Water Consumption of Paris, stated in a note on p. 215 of our issue of last week to be 320,000 cu. m. per day, should be 420,000 cu. m. daily. This per diem consumption of 111,000,000 gals. is a per capita per diem consumption of 37 gals., which corresponds very closely to the 37.9 gals. per capita per diem reported for 1911 for London, by the Metropolitan Water Board.

A Large Water Filtration Plant for New York City has been under consideration for a number of years, and quite recently an appropriation between $8,000,000 and $9,000,000 for construction work has been made. The general proposition is to build a plant with a daily capacity of 400,000,000 gals. on the site of what was originally intended to be the eastern basin of the Jerome Park Reservoir. Plans for a sand filtration plant at this location were made three years ago, by the Department of Water Supply, Gas and Electricity, under the direction of Mr. I. M. de Varona, M. Am. Soc. C. E., Chief Engineer of the department. These plans will now be reviewed and brought up to date and plans and specifications will also be prepared for a mechanical filtration plant, with the idea of comparing the advantages and estimated cost of each and choosing between the two types. A filtration staff of 18 men is to be created, including men outside and within the department. Among 14 men thus far appointed to the staff, the following have been chosen from without the department: Mr. Geo. W. Fuller, M. Am. Soc. C. E., New York City, Consulting Expert; Mr. Elmer G. Manahan, M. Am. Soc. C. E. (until recently of the firm of Hering & Fuller, New York City), immediately in charge of design under Mr Fuller; Mr. Thos. C. Atwood, Assoc. M. Am. Soc. C. E., until recently with the Board of Water Supply, New York City; Mr. Charles P. Bueger, who for a long time was employed on filtration, design and construction work in Philadelphia. Mr. Henry S. Thompson is Commissioner of Water Supply, Gas and Electricity, New York City.

A Cable Message was sent around the world on Aug. 21, by the New York "Times" in 16½ min., the message being handled as ordinary commercial business. The cablegram was relayed at San Francisco, Honolulu, Midway Island, Manila, Hongkong, Saigon, Singapore, Madras, Bombay, Aden, Suez, Port Said, Alexandria, Malta, Gibraltar, Lisbon and the Azores. In all 21,397 nautical miles (24,963 land miles) of submarine cable and 3,650 land miles of telegraph line were traversed.

An Extension of the Electric Railway Line of the Ocean Electric Ry., in the Borough of Queens, New York City, has been denied by the Public Service Commission for the First District of New York, in an opinion recently published. This company operates on Rockaway Beach, a bar lying between Jamaica Bay and the ocean. The West Rockaway Land and Neponsit Realty companies desired a single track of this electric railway westerly through their land developments and gave rights in perpetuity to the railway company for lines to extend along private streets which were later to be ceded to the city. The commission held (1) that there were no inhabitants yet in the vicinity and no public necessity, and (2) that granting the extension would give the railway perpetual rights on the streets after being ceded to the city. This last result was held to be against the spirit of the statute limiting the life of such franchises and to open the way for evasion of the law in other cases.

A Certificate of Public Convenience, applied for by the Buffalo; Rochester & Eastern R. R. Co., to enable it to build a steam railroad between Buffalo and Troy, N. Y., has for the second time been denied by the Public Service Commission of the Second District of the state named. The previous rejection was made on March 15, 1909. The Commission is strongly of the opinion that the railroad is still unable to prove its financial ability to construct such a railroad or come anywhere near earning enough to pay charges if the road were built.

A Compromise City Charter for Atlanta, Ga., is said to have been agreed upon by a committee of the State Legislature and some of the officials and citizens at Atlanta. The plan is to substitute for the present City Council of 30 members a council of 10 men representing the 10 wards of the city, but chosen both in the primaries and final elections by the vote of the entire city; also to substitute for the many existing administrative boards (except the Board of Education) a single board of five members, including the Mayor. The powers of the council would be restricted to legislation and levying taxes. The administrative board would have charge of everything of an executive nature except educational work, and would also control appropriations. The councilmen would be elected for terms of two years and receive salaries of $300 a year. The Mayor would be elected for two years and be paid $6,000 a year, while the other four members of the administrative board would be elected for four years and be paid $5,000 a year. An unusual recall feature is provided to the effect that any seven of the ten members of the council may publish reasons for the recall of any member of the administrative board and set a date for an election, at which the person under recall may stand for reelection if he sees fit. A board of education of five members would be chosen by the administrative board to act in conjunction with the Commissioner of Schools. Curiously enough, while this proposed charter is described as a satisfactory compromise, one of the reasons given for not submitting the charter to popular vote is that it would result in a bitter conflict between those favoring and those opposing the commission plan.

The Power Development on the Los Angeles Aqueduct is to be increased from 120,000 HP. to 150,000 by developments on Cottonwood and Division Creeks in Mono County. On Aug. 8, the Los Angeles City Council authorized Mr. Wm. Mulholland, Chief Engineer of the Aqueduct, to file claims for water rights in conformity with recent legislation giving municipalities prior rights to water and power on all streams in the state. (For an outline of the earlier Aqueduct power developments see Eng. News. March 24 and Dec. 29, 1910).

An Unusual Irrigation Project is about to be undertaken in the San Joaquin Valley, just south of Stockton, Cal. This project, which is being carried out by the South San Joaquin Irrigation District, under the provisions of the Wright-Bridgeford Act of the State of California, is different from most other irrigation schemes in that the irrigation is to be applied to lands already under a fair degree of cultivation and not arid and worthless. The land is now producing an annual value of at least 2½ million dollars for the 71,050 acres, and is being held at about $35 per acre. By the aid of irrigation it is expected that the production will be so increased as to make the land worth two or three times its present value. Another unusual feature is that the Directors of the District have pledged themselves to build a complete distribution system and thus bring water to all owners of land instead of building, as in most cases, only the main canal

and the principal laterals. The total bond-issue authorized is $1,875,000, or $26.40 per acre. The present population of the District is about 3,500.

The works to be built, part of which are now under contract, comprise a concrete diversion dam 450 ft. long and 75 ft. maximum height, of a peculiar multiple arch type with two arches abutting against a main buttress in the channel; concrete head and regulating works, and about 17 miles of conduit, of which about 6,000 ft. is in tunnel, 2,000 ft. on a reinforced-concrete flume and the rest in concrete-lined open canal. These all constitute the supply system and bids for a distributing system will be asked later.

Mr. Edwin Duryea, Jr., M. Am. Soc. C. E., of San Francisco, is Chief Engineer for the District.

The Common Roller Towel, as well as the public drinking cup, has recently been tabooed in Chicago by a city ordinance passed by the City Department of Health. The drinking-cup ordinance became effective on Aug. 8 and the roller-towel ordinance on Aug. 10. Each ordinance is published in full in the weekly Bulletin of the Chicago Department of Health for Aug. 5, 1911. A state law against the public drinking cup went into effect on July 1, 1911.

Personals.

Mr. Walter H. Donley has been appointed Master Mechanic of the Illinois Central R. R. at East St. Louis, Ill., succeeding Mr. F. G. Colwell, resigned.

Mr. George I. Gay, formerly Instructor at the University of Illinois, has been appointed Instructor in Civil Engineering at the University of California.

Mr. F. J. Allen, formerly Resident Engineer of the Missouri & North Arkansas R. R., at Eureka Springs, Ark., has been appointed Engineer of Maintenance-of-Way for the same road.

Mr. E. M. Weaver, formerly Signal Engineer of the Long Island R. R., has been appointed Engineer of Maintenance-of-Way of the same road, succeeding Mr. J. B. Austin, promoted.

Mr. R. H. Corey, Assoc. M. Am. Soc. C. E., Assistant Engineer of the Water Department of Portland, Ore., has resigned to accept a position with the Pacific Light & Power Co., with headquarters in Portland.

Mr. A. De Bernadi, formerly Superintendent of the Missouri Pacific Ry., at Falls City, Neb., has been promoted to General Superintendent of the Western District of the same road with offices at Kansas City, Mo., succeeding Mr. W. J. McKee, resigned.

Mr. W. W. Young, a consulting engineer of New York City and Philadelphia, Pa., has been appointed Consulting Engineer for the Bronx Valley Sewer Commission. Mr. Young has been connected with the work of the commission for the past seven years.

Mr. T. H. Hogg, Assistant to the Superintendent of Construction of the Ontario Power Co., Niagara Falls, Ont., has been appointed Managing Editor of the "Canadian Engineer" of Toronto, Ont. Mr. Hogg is a graduate of Toronto University, class of 1907.

Mr. Austin B. Fletcher, M. Am. Soc. C. E., Secretary-Engineer of the Highway Commission of San Diego County, Cal., has been appointed State Highway Engineer of California at a salary of $10,000 per annum. Mr. Fletcher was for many years Secretary of the Massachusetts Highway Commission.

Mr. Richard W. Sherman, M. Am. Soc. C. E., President of the Troy Public Works Co., of Utica, N. Y., has been appointed Chief Engineer of the New York State Conservation Commission. Mr. Sherman is a brother of the Vice-President of the United States and has been City Engineer and Mayor of Utica.

Mr. A. S. Abbott, Master Mechanic of the St. Louis & San Francisco R. R., at Sapulpa, Okla., and Mr. J. Foster, Master Mechanic of the same road at Kansas City, Mo., have been promoted to the positions of Mechanical Superintendent of the First and Second Districts, respectively, with headquarters at Springfield, Mo.

Mr. Wm. Paul Gerhard, M. Am. Soc. M. E., Consulting Hydraulic and Sanitary Engineer of New York City, has been awarded the honorary degree of Doctor of Engineering by the Technical University of Darmstadt, Germany. This degree is awarded for conspicuous merits in promoting the technical sciences by the unanimous vote of the faculty and the senate of the university.

Mr. Fred W. Sarr, Assoc. M. Am. Soc. C. E., Division Engineer of the Fourth Division, at Syracuse, N. Y., New York State Highway Department, has resigned. He is succeeded by Mr. Fred S. Strong, formerly Assistant Engineer of the same division. Ill health is given as the reason for Mr. Sarr's resignation. The position pays $3,000 per annum.

Mr. Clarence Goldsmith, Assoc. M. Am. Soc. C. E., has been granted a year's leave of absence as Hydraulic Engineer with the Committee on Fire Prevention of the National Board of Fire Underwriters, and during this time will supervise the installation of the new high-pressure system of water mains for fire protection in the business district of Boston, Mass.

Mr. Elmer G. Manahan, M. Am. Soc. C. E., for the past three years a member of the firm of Hering & Fuller, Consulting Engineers, New York City, has been appointed Division Engineer of the Department of Water Supply, Gas and Electricity of the City of New York, in joint charge with Mr. T. C. Atwood of the filtration plant to be constructed for the Croton water supply.

Mr. Thomas C. Atwood, Assoc. M. Am. Soc. C. E., for the past four years Division Engineer of the Board of Water Supply, City of New York, in charge of the design and construction of the Bronx division of the Catskill aqueduct, has been appointed Division Engineer of the Department of Water Supply, Gas and Electricity of the City of New York, in joint charge with Mr. E. G. Manahan of the filtration plant to be constructed for the Croton water supply.

Mr. A. M. Burt, Superintendent of the Fargo Division of the Northern Pacific Ry. at Dilworth, Minn., has been appointed Superintendent of the Rocky Mountain Division of the same road at Missoula, Mont., succeeding Mr. M. M. Fowler, who has resigned. Mr. Burt is succeeded at Dilworth, Minn., by Mr. B. O. Johnson, formerly Superintendent of the Yellowstone Division at Glendive, Mont. Mr. T. H. Lantry, Trainmaster at Spokane, Wash., succeeds Mr. Johnson at Glendive.

Prof. O. P. Hood, M. Am. Soc. M. E., head of the departments of mechanical and electrical engineering of the Michigan College of Mines, has accepted an appointment as Chief Mechanical Engineer of the United States Bureau of Mines, and after September will make his headquarters in Pittsburgh, Pa. Prof. Hood graduated from Rose Polytechnic Institute in 1885, and from 1886 to 1898 was Professor of Mechanical Engineering at the Kansas State Agricultural College. Since 1898 he has been Professor of Mechanical and Electrical Engineering at the Michigan College of Mines. Prof. Hood is also a member of the American Institute of Mining Engineers and has carried on an extensive consulting practice for several years.

Obituary.

Francis Collingwood, M. Am. Soc. C. E., died on Aug. 18 at Avon-by-the-Sea, N. J. A biographical sketch of Mr. Collingwood will appear in a later issue.

Capt. John Cross, for many years prominent as a railway promoter, died at his home in Los Angeles, Cal., on Aug. 5, aged 70 years. Recently he had been interested in promoting the San Francisco Short Line R. R.

William Arthur Hungerford, Manager of the Canadian Talc & Silica Co., of Eldorado, Ont., and a prominent mining engineer, died on Aug. 15 at his home in Madoc, Ont. He was born in Ireland in 1847 and came to Canada when 17 years of age.

Joseph Heckart Frazer, Jun. Am. Soc. C. E., died recently at Aruro, Bolivia, from pneumonia. Mr. Frazer was a native of Newark, Del., and graduated from Delaware College in 1903. He had been engaged in contract work in Bolivia for the past seven years.

James H. Lappin, formerly an engineer employed by the Department of Bridges, City of New York, and in the Department of Water Supply, Gas and Electricity, died recently at his home in New York City. He was 50 years old and an employee of the city for many years.

Omar N. Steele, Manager of the American Shipbuilding Co.'s works at Cleveland, Ohio, died in that city from apoplexy on Aug. 17. He was born in 1843 and served throughout the Civil War in an Ohio regiment. He had been associated with the Cleveland Shipbuilding Co. and its successor, the American Shipbuilding Co., for 37 years.

Engineering Societies.

COMING MEETINGS.

TRAVELING ENGINEERS' ASSOCIATION.
Aug. 29-Sept. 1. Annual convention at Chicago, Ill. Secy., W. O. Thompson, N. Y. C. Car Shops, East Buffalo, N. Y.

INTERNATIONAL ASSOCIATION OF MUNICIPAL ELECTRICIANS.
Sept. 12-15. Annual meeting at St. Paul, Minn. Secy., Clarence R. George, Houston, Tex.

MASTER CAR AND LOCOMOTIVE PAINTERS' ASSOCIATION.
Sept. 12-15. Annual convention at Atlantic City, N. J. Secy., A. P. Dane, Boston & Maine R. R., Reading, Mass.

ROADMASTERS AND MAINTENANCE OF WAY ASSOCIATION.
Sept. 12-15. Annual meeting at St. Louis, Mo. Secy., W. E. Emery, Peoria, Ill.

COLORADO ELECTRIC LIGHT, POWER AND RAILWAY ASSOCIATION.
Sept. 13-15. Annual convention at Glenwood Springs, Colo. Secy., F. D. Morris, P. O. Box 1052, Colorado Springs, Colo.

NEW ENGLAND WATER WORKS ASSOCIATION.
Sept. 13-15. Annual convention at Gloucester, Mass. Secy., Willard Kent, Narragansett Pier, R. I.

ASSOCIATION OF EDISON ILLUMINATING COMPANIES.
Sept. 19-21. Annual convention at Spring Lake, N. J. Secy., N. T. Wilcox, Lowell, Mass.

AMERICAN ELECTROCHEMICAL SOCIETY.
Sept. 21-23. Annual meeting at Toronto, Ont. Secy., Jos. W. Richards, Lehigh University, South Bethlehem, Pa.

MICHIGAN GAS ASSOCIATION.
Sept. 20-22. Annual meeting at Detroit, Mich. Secy., Glenn R. Chamberlain, Grand Rapids Gas Light Co., Grand Rapids, Mich.

ILLUMINATING ENGINEERING SOCIETY.
Sept. 25-27. Annual convention at Chicago, Ill. Secy., Preston S. Millar, 29 West 39th St., New York City.

AMERICAN SOCIETY OF MUNICIPAL IMPROVEMENTS.
Sept. 26-29. Annual convention at Grand Rapids, Mich. Secy., A. P. Folwell, 239 West 39th St., New York City.

AMERICAN MINING CONGRESS.
Sept. 26-29. Annual session at Chicago, Ill. Secy., J. F. Calibreath, Denver, Colo.

LEAGUE OF AMERICAN MUNICIPALITIES.
Oct. 4-6. Annual convention at Atlanta, Ga. Secy., John MacVicar, Department of Streets, Des Moines, Iowa.

AMERICAN ELECTRIC RAILWAY ASSOCIATION.
Oct. 9-13. Annual convention at Atlantic City, N. J. Secy., H. C. Donecker, 29 West 39th St., New York City.

NATIONAL ASSOCIATION OF RAILWAY COMMISSIONERS.
Oct. 10. Annual convention at Washington, D. C. Secy., Wm. H. Connolly, Washington, D. C.

AMERICAN INSTITUTE OF MINING ENGINEERS.
Oct. 10-17. Annual convention at San Francisco, Cal., followed by trip to Japan. Secy., Joseph Struthers, 29 West 39th St., New York City.

RAILWAY SIGNAL ASSOCIATION.
Oct. 10-12. Annual convention at Colorado Springs, Colo. Secy., C. C. Rosenberg, Bethlehem, Pa.

AMERICAN RAILWAY BRIDGE AND BUILDING ASSOCIATION.
Oct. 17-19. Annual convention at St. Louis, Mo. Secy., C. A. Lichty, C. & N. W. Ry., Chicago, Ill.

AMERICAN GAS INSTITUTE.
Oct. 18-20. Annual convention at St. Louis, Mo. Secy., A. B. Beadle, 29 West 39th St., New York City.

Institute of Operating Engineers.

The first formal annual meeting will be held in the Engineering Societies Bldg., New York City, Sept. 1-3. Session for the presentation of technical papers will be held Sept. 1 at 2 p. m. and Sept 2 at the same hour. Among the papers to be presented are the following: "A Boiler Room Analysis of Coal," J. P. Fleming; "Cooling Towers versus Steam Pumps," Henry W. Geare, Chief Engineer, Peter Doelgers Brewery; "Engine Lubrication," R. D. Tomlinson, Engineer in charge of engines and condensers, Allis-Chalmers Co., Milwaukee, Wis.; "Elements of Indication Work," F. C. Holly, Yazoo City, Miss.; "The Proximate Coal Analysis," Frank Martin, New York City; "Water in Steam Mains," John MacVicar, Boston, Mass.; "Changes in a Power Plant to Partly Comply with an Operating Engineer's Idea of Economy," Wm. I. Hart, Chicago, Ill.; "Running Without Cylinder Oil," R. B. Crockett, San Beneto, Tex; "Description of a Mixed or Combination Central Plant," J. O. Olson, Clarinda, Iowa.

The secretary is Mr. Hubert E. Collins, 29 West 39th St., New York City.

American Society of Civil Engineers.

At the Aug. 18 meeting of the San Francisco Association of members of this society, Mr. C. H. Snyder presented an illustrated paper on "Some Recent Developments in Concrete-Steel Building Construction."

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